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ABSTRACT

A four-year longitudinal study of concept attainment and uses of concepts, as specified by the Conceptual Learning and Development Model, is described. Data collected during the first two years were based upon the assessment of the concept, equilateral triangle. The assessment battery was administered to 351 children (grades K, 3, 6, and 9) in 1973 and 1974, to two control groups, and to a different sample of 275 children. Age changes in children's conceptual development were predicted according to the model, and were strongly supported by both sets of data. The concept was attained according to the four sequential levels: concrete, identity, classificatory, and formal. Children who had attained the concept at the formal level were increasingly able to use the concept in cognizing supraordinate-subordinate relationships, understanding principles, and solving problems. Progression in mastery of higher levels of concept attainment was associated with ability to apply the concept for the three uses. Participation in the assessment of level of attainment had no biasing effect on either level of attainment or uses of the concept. The resulting data are presented.
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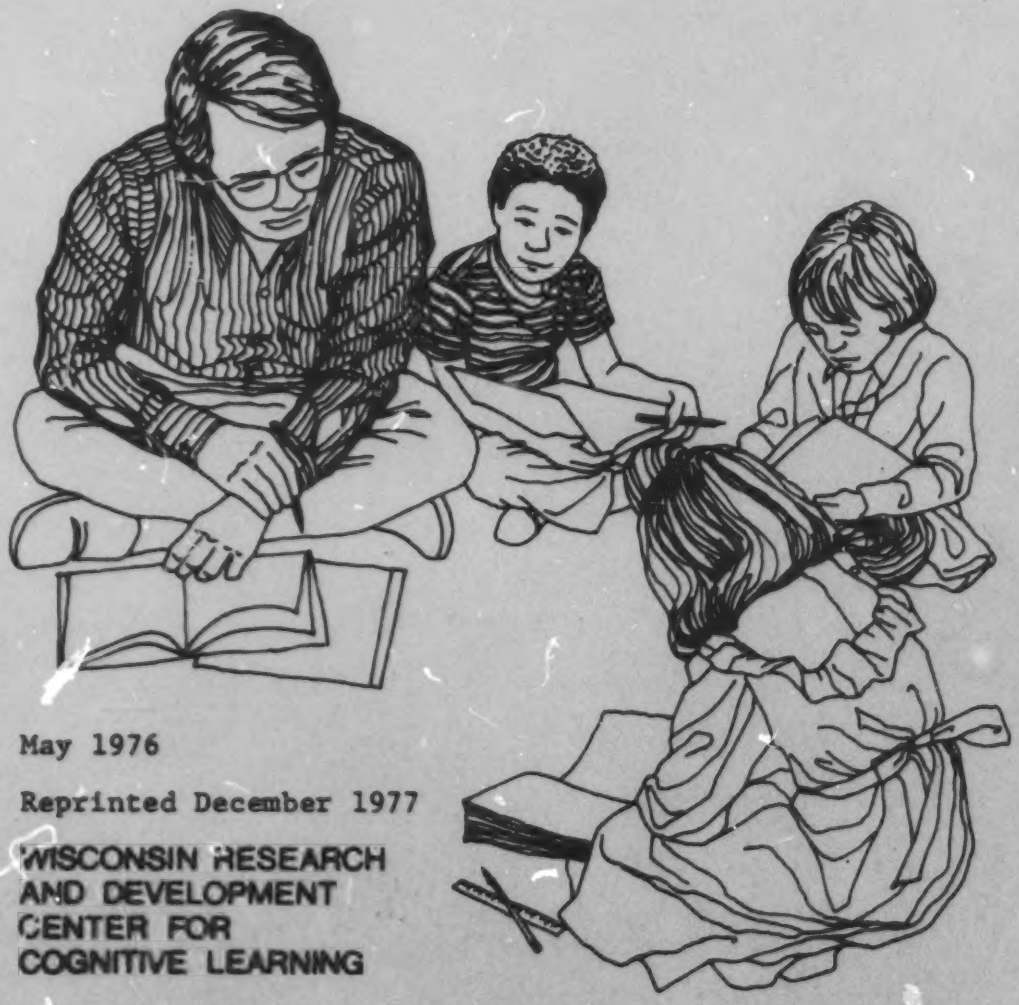
Technical Report No. 425

FIRST LONGITUDINAL STUDY OF ATTAINMENT OF THE CONCEPT EQUILATERAL TRIANGLE BY CHILDREN AGE 5 TO 16

by Herbert J. Klausmeier, Patricia S. Allen, Thomas S. Sipple, and Keith M. White



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WISCONSIN RESEARCH AND DEVELOPMENT CENTER FOR COGNITIVE LEARNING

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Report from the Project on
Children's Learning and Development

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ABSTRACT

Theory and research regarding four levels of concept attainment and three uses of concepts as specified by the conceptual learning and development (CLD) model are described. The objectives and design of a four year longitudinal assessment program of children's conceptual learning and development are presented.

This study is the first report of descriptive data collected over the first two years of longitudinal assessment. These data were based on a single assessment battery, equilateral triangle, developed to determine each child's level of concept attainment and also the related use of the concept. The battery was designed as a paper-and-pencil task and was administered initially to 351 Beloit, Wisconsin, children who were in kindergarten, third, sixth, and ninth grades in 1973 and again when the same children were in first, fourth, seventh, and tenth grades in 1974. The battery was also administered to 160 children in a retest control group and 160 children in a cohort control group. Longitudinal data based on the equilateral triangle assessment battery were also collected in 1973 and 1974 from a smaller sample of 275 children in Watertown, Wisconsin.

Predictions, based on the model, focused on age changes in children's conceptual development. These predictions were strongly supported by both sets of longitudinal data.

1. Children's attainment of the equilateral triangle concept during the first two years of assessment was in an invariant sequence according to

four successive levels: concrete, identity, classificatory, and formal. Most children either mastered the concept at the same level as the previous year or at higher levels in the sequence. Comparisons between children in the longitudinal sample and those in the retest and cohort control groups revealed no biasing effects in attainment of the four levels due to repeated participation in the longitudinal assessment or to specific cohort.

2. Children who attained the equilateral triangle concept at the formal level by year 2, in comparison with those remaining at the classificatory both years were increasingly able to use the concept (a) in cognizing supraordinate-subordinate relationships in a hierarchy where the attained concept was an element of the hierarchy, (b) in understanding principles that stated a relationship between the attained concept and one or more other concepts, and (c) in solving problems that required the use of the particular concepts. No biasing effects in mastery of the uses were found as a result of repeated testing, but cohort appeared to have some differential effect on mastery of the uses.

3. Children who gained in knowledge of the labels of the equilateral triangle concept and of its defining attributes from first to second assessments also gained in ability to master the three uses of the concept. A steady, consistent progression in acquisition of the labels of the equilateral triangle concept was observed over the first two years of assessment.

I

INTRODUCTION: CONCEPTS AND CONCEPT LEARNING

Individuals at all levels of human development are constantly learning new concepts and extending and using old concepts in new situations. It is apparent, however, that a person's level of mastery of a particular concept will vary depending upon his or her experiences with concept instances and ability to perform the cognitive operations. For example, a four-year-old child and a biologist may both have a concept of tree; although both may perform equally well when asked to identify a few obvious examples and nonexamples of tree, their concepts differ markedly. Despite the large difference in level of understanding, concepts are the fundamental agents of thought for human beings from early childhood through adulthood.

A substantial amount of research on concept learning has been completed during the past two decades dealing with the internal and external conditions of concept learning. Content analyses of concepts and behavioral analyses of concept learning related to various subject-matter fields have also been conducted. Sufficient knowledge has accrued so that Klausmeier, Ghatala, and Frayer (1974) were able to formulate a model that specifies and describes the cognitive operations involved in the attainment of concepts at specifiable

levels of mastery by individuals whose abilities change in predictable ways with age. (We use "age" as a shorthand term to indicate the product of learning and maturation; age, per se, is not considered a determining factor of how well individuals can perform.)

An analytical, descriptive model of conceptual learning and development (CLD model) was initially formulated by Klausmeier (1971) and described more fully by Klausmeier, Ghatala, and Frayer (1974). The model defines four levels of concept attainment and the possible uses and extensions of attained concepts, specifies the cognitive operations involved in learning concepts at each of the four levels, and postulates internal and external conditions of learning related to the specified levels. The levels of concept mastery, the operations, and the conditions of learning have been identified through content analyses of concepts and behavioral analyses of concept learning tasks, and through empirical research in laboratory and school settings carried out at the Wisconsin Research and Development Center for Cognitive Learning and other research laboratories.

THE NATURE OF CONCEPTS

The word concept is used by Klausmeier, Ghatala, and Frayer (1974) to designate mental constructs of individuals and also identifiable public entities that comprise part of the substance of the various disciplines. Thus, concept is used appropriately in two different

contexts just as many other English words are. A concept is defined as ordered information about the properties of one or more things--objects, events, or processes--that enables any particular thing or class of things to be differentiated from, and also related to, other things or classes of things.

In regard to concepts as mental constructs, it is noted that maturing individuals attain concepts according to their unique learning experiences and maturational patterns. In turn, the concepts that are attained are used in the individual's thinking about the physical and social world.

Concepts as public entities are defined as organized information corresponding to the meaning of words. Carroll (1964) related concepts, words, and word meanings in the following way. Words in a language can be thought of as a series of spoken or written entities. There are meanings for words that can be thought of as standards of communicative behavior shared by those who speak a language. Finally, there are concepts--that is, the classes of experiences formed in individuals either independently of language processes or in close dependence on language processes. Putting the three together, Carroll stated: "A 'meaning' of a word is, therefore, a societally standardized concept, and when we say that a word stands for or names a concept it is understood that we are speaking of concepts that are shared among members of a speech community [1964, p. 187]."

At the inception of a large programmatic research effort dealing with concept learning and instruction, Klausmeier, Davis, Ramsay, Fredrick, and Davies (1965) formulated a conception of concept in terms of defining attributes common to many concepts from various disciplines. Klausmeier, Ghatala, and Frayer (1974) further refined the definition by specifying eight attributes of concepts: learnability, usability, validity, generality, power, structure, instance numerousness, and instance perceptibility. Other researchers and subject-matter specialists are also treating concepts in terms of defining attributes. For example, Flavell (1970) indicated that a formal definition of concept in terms of its defining attributes is useful in specifying what concepts are and what they are not and also in identifying the great variability among concepts. Markle and Tiemann (1969) and Tennyson and Boutwell (1971) have shown that the external conditions of concept learning can be delineated through research that starts with a systematic identification of the defining attributes of the particular concepts used in the research. Scholars at the Wisconsin Research and Development Center demonstrated that analysis of concepts in terms of their defining and variable attributes is useful in clarifying the meanings of the concepts drawn from four disciplines: language arts--Calub, Fredrick, Nelson, and Frayer (1971); mathematics--Romberg, Steitz, and Frayer (1971); science--Voelker, Sorenson, and Frayer (1971); and social studies--Tabachnick, Weibble, and Frayer (1970).

The CLD model deals primarily with concepts represented by words that can be defined in terms of attributes. However, some concepts are defined on other bases, including synonyms and antonyms. Further, not all words potentially definable in terms of attributes are so defined, even in unabridged dictionaries. Therefore, the researcher and also the developer of curriculum materials must ascertain the defining attributes independently or cooperatively with scholars from the various disciplines.

AN OVERVIEW OF THE CONCEPTUAL LEARNING AND DEVELOPMENT MODEL

Figure 1 shows the structure of the CLD model. Four successively higher levels in the attainment of a given concept are outlined. The four levels are concrete, identity, classificatory, and formal. As a concept is attained by an individual at the successive levels, it becomes increasingly usable and valid, as defined earlier.

A second part of Figure 1 shows the ways in which concepts may be extended and used. Concepts acquired at only the concrete and identity levels can be used to solve simple problems that require only the relating of obvious sensory perceptions. For example, to save time or for some other reason, children may walk diagonally across a rectangular block rather than remaining on the sidewalk and walking around a corner of the block. They need not have attained the concepts of distance, angle, diagonal, or straight line at the classificatory level.

Concepts acquired at the classificatory and formal levels may be

LEVELS OF CONCEPT ATTAINMENT

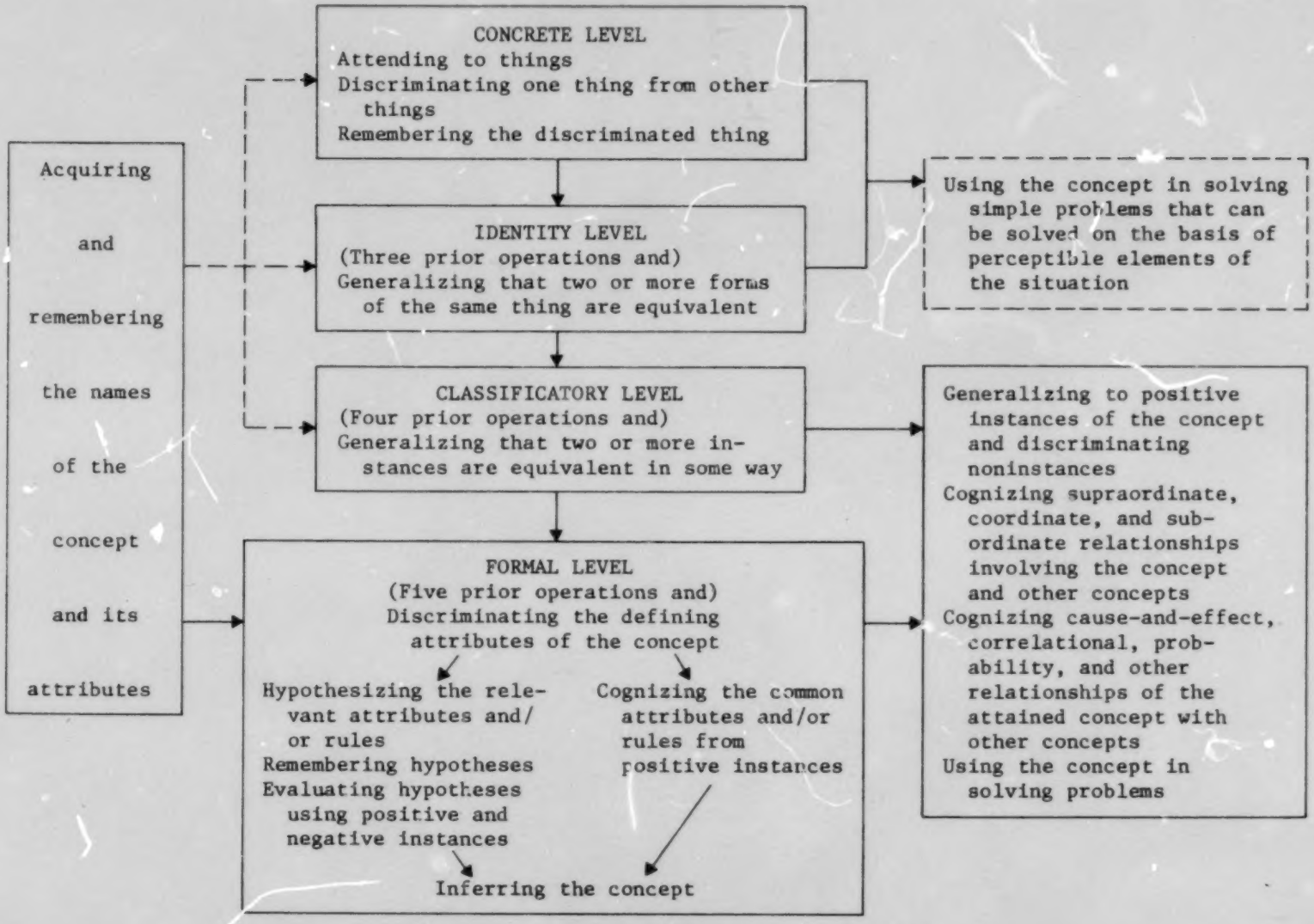
Acquiring and remembering the names of the concept and its attributes
CONCRETE LEVEL
Attending to things
Discriminating one thing from other things
Remembering the discriminated thing
IDENTITY LEVEL
(Three prior operations and)
Generalizing that two or more forms of the same thing are equivalent
CLASSIFICATORY LEVEL
(Four prior operations and)
Generalizing that two or more instances are equivalent in some way
FORMAL LEVEL
(Five prior operations and)
Discriminating the defining attributes of the concept
Hypothesizing the relevant attributes and/or rules
Remembering hypotheses
Evaluating hypotheses using positive and negative instances
Cognizing the common attributes and/or rules from positive instances
Inferring the concept
Using the concept in solving simple problems that can be solved on the basis of perceptible elements of the situation
Generalizing to positive instances of the concept and discriminating noninstances
Cognizing supraordinate, coordinate, and subordinate relationships involving the concept and other concepts
Cognizing cause-and-effect, correlational, probability, and other relationships of the attained concept with other concepts
Using the concept in solving problems

Figure 1. Cognitive operations and concept learning

generalized to newly encountered instances, related to other concepts, and used in problem-solving situations. Here we are concerned with both transfer of learning and the use of concepts in thinking.

Figure 1 also shows the operations involved in attaining a concept at each level. Attending to and discriminating objects and then remembering what was discriminated are involved in attaining a concept at the concrete level. The same operations are also involved at each subsequent level and are supplemented with the higher-level operations of generalizing, hypothesizing, and evaluating.

Although some of the same operations are posutlated to occur at various levels, what is operated on and remembered changes with the attainment of the successively higher levels. That is, the operations are carried out on more sharply differentiated and abstracted stimulus properties at the four successive levels.

By focusing on the attainment of successively higher levels of the same concept, we are able to clarify the short-term learning conditions at each level and to describe conceptual development over long time intervals. Thus, the model provides a basis for organizing knowledge and carrying out research related to both the external and internal conditions of learning at each of the four levels.

The fourth part of the model shows that acquiring and remembering the name of the concept may come at any of the four levels. The solid line indicates that being able to name the concept and its relevant attributes is essential to attaining the concept at the formal level.

The broken lines indicate that an individual may acquire the name at about the same time he first attains the concept at the lower levels, but that this is not requisite. For example, a young child might attain a concept at all three lower levels but not have acquired the concept name. The younger the children are when they attain the concept, the less likely they are to have the name for it.

At this time, we shall delimit the substantive domain that we are treating. The model in its totality describes the four levels of concept attainment and uses of the same concept rather than each of four kinds of concepts. The four levels apply to the many concepts that are or can be defined in terms of attributes and which have actual perceptible instances or readily constructed representations of instances. We have already cited a few examples of this kind, including all the concepts comprising the plant kingdom and the animal kingdom. However, the operations at each level are intended to be applicable also to different kinds of concepts, some of which, because of their nature, are not attainable at all four levels. We can specify these kinds of concepts and the levels at which they can be attained.

There are some concepts for which there is only one instance, such as the earth's moon and Abraham Lincoln, and some that have many identical instances, for example, inch and pound. Related to Figure 1, such single-instance or identical-instance concepts which have defining attributes can be attained at the concrete, identity, and formal levels, but not at the classificatory level. By our definition of classificatory level,

there must be at least two nonidentical instances that can be placed in the same class. Therefore, some concepts cannot be attained at the classificatory level.

Other concepts are of such low validity that there may not be agreement as to their defining attributes, for example, beauty and morality. Concepts such as these might be learned at the three lower levels but not at the formal level.

Finally, there are concepts with no perceptible instances, such as infinity and atom. These cannot be learned at the three lower levels but might be learned at the formal level.

Returning to the four levels given in Figure 1, we postulate that attaining a concept at the four successively higher levels is the normative pattern for large numbers of individuals under two conditions. First, the concept is of the kind for which there are actual perceptible instances or readily constructed representations; and second, the individual has experiences with the instances or representations starting in early childhood. Furthermore, in order to proceed to the formal level, individuals must acquire labels for the concept and for its attributes. For example, the individual will have successively attained the concrete, identity, and classificatory levels of the concept plant before he describes and treats plant formally in terms of its defining attributes.

Children have direct experiences during preschool years with many things and attain concepts of these things at the first two levels. They also attain many concepts at the beginning classificatory level and

learn the societally accepted names for the concepts and their attributes through formal and informal instruction.

Earlier we indicated that some individuals, because of environmental conditions, may not encounter actual instances of a concept; rather, they experience instances only in verbal form. Thus, these individuals may attain a concept at either the classificatory or the formal level at the outset. It is also noted that the mature person, although capable of attaining a concept at the formal level, may stop at a lower level of attainment because of the way in which the perceptible instances are encountered or other conditions of learning.

OPERATIONS RELATED TO LEVELS OF CONCEPT ATTAINMENT

Having considered the overall features of the model, we may take up the operations in more detail, starting with those pertaining to the concrete level.

Concrete Level

Attainment of a concept at the concrete level is inferred when the individual cognizes an object that he or she has encountered on a prior occasion. We use the tern "operations" as Guilford (1967) does. Guilford has defined the operations of cognition, memory, productive thinking, and evaluation in terms of test performances. He stated that cognition must be related to the products cognized and he formally defined cognition as follows:

> Cognition is awareness, immediate discovery or rediscovery, or recognition of information in various forms: comprehension or understanding. . . . The most general term, awareness, emphasizes having active information at the moment or in the present. . . . The term, recognition, is applied to knowing the same particular on a second encounter. . . . If cognition is practically instantaneous, call it recognition; if it comes with a slight delay, call it "immediate discovery" [pp. 203-204].

The first step in attaining this level is attending to an object and representing it internally. Woodruff (1961) pointed out that:

> All learning begins with some form of personal contact with actual objects, events, or circumstances. . . . The individual gives attention to some object. . . . Through a light wave, or a sound wave, or some form of direct contact with a sensory organ in the body, an impression is picked up and lodged in the mind [p. 66].

Gagné (1970) indicated that as individuals attend to an object, they discriminate it from other objects. Woodruff (1961) called the outcome of these attending and discriminating operations a concrete concept, a mental image of some real object experienced directly by the sense organs. The infant, for example, attends to a large red ball and a white plastic bottle, discriminates each one, maintains a mental image of each, and cognizes each of the objects when experienced later.

The discrimination of objects involves attending to distinctive features that serve to distinguish the objects from one another. Thus, children learn very early to respond to gross differences in such features of objects as size, shape, color, and texture. As children mature, they become capable of making finer discriminations involving these and other features.

Attainment of a concept at the concrete level thus requires attending to the distinctive features of an object and forming a memory image which represents the object as a unique bundle of features. The concept at this level may or may not be associated with the concept label, depending on whether the label has been learned and remembered, and whether it has been associated with the concept.

The preceding analysis of the operations in attaining concepts at the concrete level is sufficiently comprehensive to include motoric experiencing of objects. That is, an object may be manipulated physically and represented enactively, as well as explored visually and represented iconically, to use Bruner's (1964) terminology. The model postulates that attending, discriminating, and remembering are involved in sensorimotor experiencing, to use the terms of Piaget (1970), as well as in the visual perception of objects.

Identity Level

Attainment of a concept at the identity level is inferred when the individual cognizes an object as the same one previously encountered when observed from a different perspective or sensed in a different modality. For example, making the same response to the family poodle when seen from straight ahead, from the side, and from various angles is evidence of the child's having attained the concept of poodle at the identity level. Whereas concept attainment at the concrete level involves only the discrimination of an object from other objects, attainment at the identity level involves both discriminating various forms

of the same object from other objects and also generalizing the forms as equivalent. Generalizing is the new operation postulated to emerge as a result of learning and maturation that makes attainment at the identity level possible.

As noted earlier, there are some valid and powerful concepts, such as the English alphabet, for which there is only one instance but which can be represented in different ways, e.g., aurally and in printed form. These concepts are typically learned at the concrete and identity levels but not at the classificatory level. Therefore, individuals proceed directly from the identity to the formal level with this kind of concept.

Bruner, Goodnow, and Austin (1956) have pointed out that identity responses occur very early in life and that the capability to recognize identity may be innate and merely extended to new events through learning. Vernon (1970) indicates that infants have to learn by experience that objects and events in the environment are permanent even though they may change their appearance from time to time as their distance and orientation changes. Clearly, the capacity to recognize identity, indeed the expectation of the continuity of objects and events in the environment, is well developed in the perception of adults.

Recognition of object identity is central to Piaget's formulations. According to Elkind (1969), Piaget's conception of concept emphasizes the variability that occurs within things--changes in state, form, and appearance which can occur to any entity.

Elkind pointed out further that American psychologists have tended

to ignore this within-instance variability of concepts and have emphasized the discriminative response aspect of concept attainment by which positive instances are cognized and discriminated from noninstances. Elkind summarized the two points of view thus:

> From the discriminative response point of view, the major function of the concept is the recognition or classification of examples. The Piagetian conception, however, assumes that a major function of the concept is the discrimination between the apparent and the real. This discrimination, in turn, can be reduced to the differentiation of between- and within-things types of variability. Here again, a comprehensive conception of a concept must include both functions because, in fact, every concept does serve both purposes [1969, p. 187].

The present model proposes that a concept is attained at the identity level temporally before it is attained at the classificatory level. Stated differently, persons must be able to cognize various forms of the same objects as equivalent before they are able to generalize that two or more different objects belong to the same class.

Classificatory Level

The lowest level of mastery at the classificatory level is inferred when individuals respond to at least two different instances of the same class as equivalent, even though they may not be able to describe the basis for their response. For example, when children treat the family's toy poodle and the neighbor's miniature poodle as poodles, although they may not name the attributes of poodles, they have attained the concept at the classificatory level.

While generalizing that at least two different instances are

equivalent in some way is the lower limit of this level of concept learning, persons are still at the classificatory level of concept learning when they can correctly classify a larger number of instances as examples and nonexamples, but cannot accurately describe the basis for their grouping in terms of the defining attributes. Henley (cited in Deese, 1967), like many other researchers, has observed this phenomenon. Many of her subjects were able to sort cards correctly into examples and nonexamples of the concepts being learned, yet gave totally erroneous definitions of the concepts.

Formal Level

A concept at the formal level is inferred when the individual can give the name of the concept, can discriminate and name its intrinsic or societally accepted defining attributes, can accurately designate instances as belonging or not belonging to the set, and can state the basis for their inclusion or exclusion in terms of the defining attributes. For example, maturing children demonstrate a concept of dog at the formal level if, when shown dogs, foxes, and wolves of various sizes and colors, they properly designate the dogs as such, call them "dogs," and name the attributes that differentiate the dogs from the foxes and wolves. The distinctive aspect of this level of concept mastery is the learner's ability to specify and name the defining attributes and to differentiate among newly encountered instances and noninstances on the basis of the presence or absence of the defining attributes.

As noted in Figure 1, the labels for the concept and the defining attributes may be learned at any of the three lower levels, but are not essential at those levels. Similarly, the discrimination of the defining attributes may occur prior to the formal level, but this is not essential. Thus, discrimination of things on their global and diffuse stimulus properties which is essential at the concrete level changes to discrimination of more specific and abstract properties at the identity and classificatory levels. However, at the formal level the individual must be able to discriminate and label all the defining attributes of the concept.

The operations involved in the learning of concepts at the formal level are also shown in Figure 1. The first operation given at the formal level is that of discriminating the attributes. As already noted, for some concepts with obvious attributes such as color and form, the discriminations may have occurred at earlier levels. However, making the discriminations and having the labels for the attributes are both essential at the formal level. This is true whether the individual infers the concept by hypothesizing and evaluating relevant attributes or cognizing the attributes common to positive instances, as shown in Figure 1.

Individuals differ in their ability to analyze stimulus configurations into abstract dimensions or attributes. There is evidence (Gibson, 1969) that this ability develops with age. Retarded children may have difficulty with simple concept learning tasks because of the

difficulty in learning to select out and attend to specific dimensions (Zeaman & House, 1963). Even among children of adequate intelligence, there are those who characteristically analyze the stimulus field and apply labels to attributes while others tend to categorize on the basis of a relatively undifferentiated stimulus (Kagan, Moss, & Sigel, 1963).

Orienting instructions may be given to make explicit the attributes of the stimuli (Klausmeier & Meinke, 1968). These instructions facilitate the learning of concepts at the formal level by assuring that the learner knows all of the attributes that may be relevant to the concept.

Having discriminated and named the attributes, an individual may infer the formal level of a concept inductively in either of the two ways shown in Figure 1. One way involves formulating and evaluating hypotheses and the other involves cognizing the common attributes in positive instances. Which strategy a learner uses depends on the instructions he has been given, his age, and the kind of concept instances he experiences.

Levine (1963) defined a hypothesis as the subject's prediction of the correct basis for responding. In the hypothesis-testing approach, learners guess a possible defining attribute or combination of attributes. They then compare this guess with verified examples and nonexamples of the concept to see whether it is compatible with them. If the guess is not compatible, they make another guess and evaluate it against

further examples and nonexamples. Eventually, they combine the information they have obtained from testing their hypotheses so as to infer all the defining attributes and thereby the concept.

Essential to the hypothesis-testing approach are the operations of remembering and evaluating hypotheses. There is support (Levine, 1963; Williams, 1971) for the idea that the subject formulates and remembers a population of hypotheses, remembers the hypotheses that were rejected, and also remembers the last one accepted as correct. In connection with evaluating hypotheses, Bruner et al. (1956) indicated that individuals determine whether or not their hypothesized concepts are valid by recourse to an ultimate criterion, test by consistency, test by consensus, or test by affective congruence. Inherent in all four procedures is establishing a criterion for judging the correctness of a hypothesis. In the present model, the validity of an individual's concept may be assessed in terms of how nearly it corresponds to expert agreement concerning the concept. Our experiments have shown that instructions to subjects which include a decision rule for evaluating hypotheses facilitate concept attainment.

The operations involved in the hypothesis-testing approach to inferring concepts appear to characterize individuals who cognize the information available to them in laboratory and classroom settings from both positive instances (examples) and negative instances (nonexamples). These individuals apparently reason like this: Instance 1 has land surrounded by water. It is a member of the class. Instance 2

has land but it is not surrounded by water. It is not a member of the class. Therefore, lands surrounded by water belong to the class and lands not surrounded by water do not. Surrounded by water is a defining attribute of the concept. This individual has attained a partial but accurate definition of the concept based on experiences with only one positive and one negative instance.

A second inductive way of inferring the concept is by noting the commonalities in examples of the concept. The commonality approach is used more often than the hypothesizing approach by children, apparently because they are either incapable of getting information from nonexamples or because they cannot carry out the hypothesizing and evaluating operations (Tagatz, 1967). The commonality strategy is the only one possible when only positive instances of the concept are available.

Our model is considered appropriate for learning concepts at the formal level by a didactic method of information presentation as well as an inductive one. That is, concepts may also be learned at the formal level deductively.[1] Many upper elementary, high school, and college students are given the names of concepts and their attributes, verbal definitions, verbal examples, and verbal nonexamples but not actual instances of the concepts. To learn the concept initially they must assimilate this information, remember it, and be able to use it in evaluating examples and nonexamples of the concept as shown in Figure 2. When learners have attained a concept initially through this kind of didactic instruction, they are able to use the concept

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[1] In explaining the model earlier, Klausmeier, Ghatala, and Frayer (1974) subsumed the deductive operations under cognizing the common attributes.

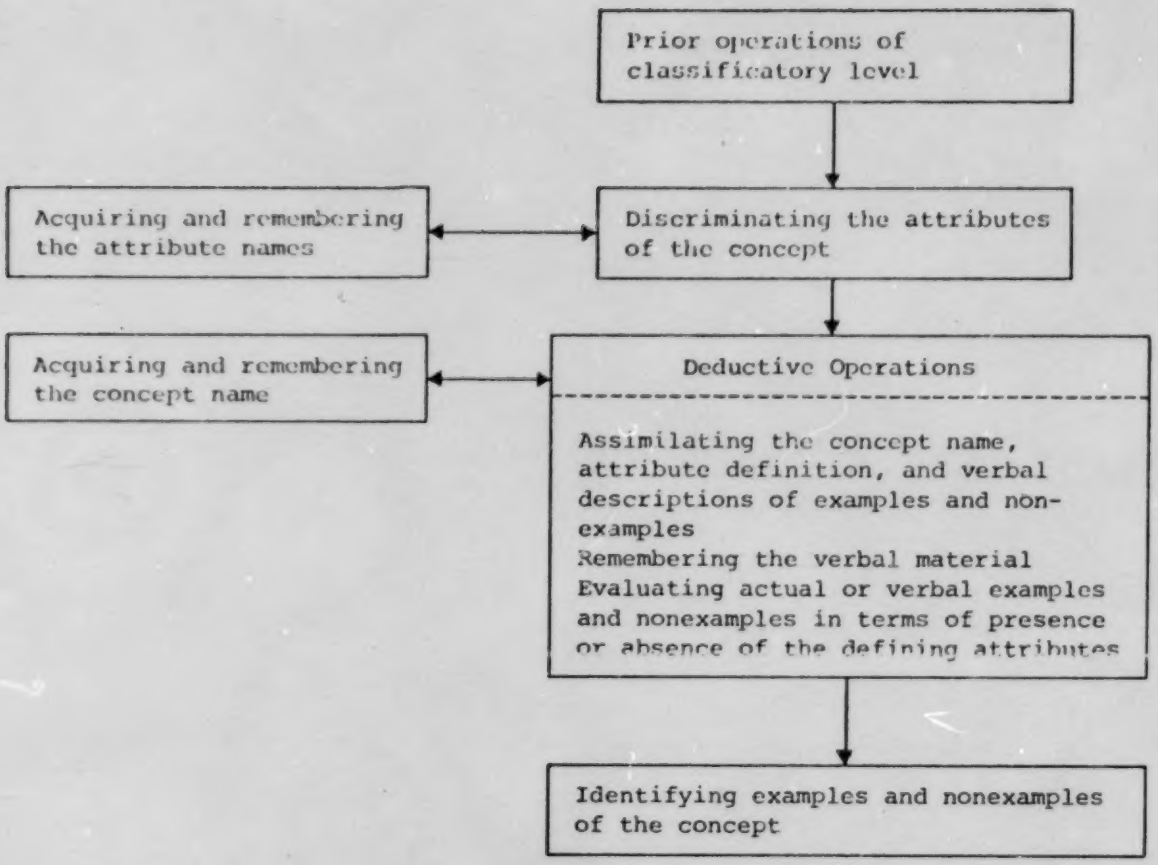
Prior operations of classificatory level
Acquiring and remembering the attribute names
Discriminating the attributes of the concept
Acquiring and remembering the concept name
Deductive Operations
Assimilating the concept name, attribute definition, and verbal descriptions of examples and non-examples
Remembering the verbal material
Evaluating actual or verbal examples and nonexamples in terms of presence or absence of the defining attributes
Identifying examples and nonexamples of the concept

Fig. 2. Cognitive operations and deductive strategies of concept attainment at the formal level.

to identify new examples and nonexamples with which they have had no prior experience. The basic operations entailed in this identification of newly encountered instances are hypothesizing whether the instance does or does not belong to the concept and evaluating the hypothesis in terms of the defining attributes that were given in the definition. Prerequisite to these two operations are discriminating the attributes of the concept and knowing their labels. All of these are listed in Figure 1 as part of the inductive strategy. Thus, when didactic instruction is used, the learner must hypothesize and evaluate regarding examples and nonexamples in order to use the newly learned concepts.

ACQUIRING APPROPRIATE LABELS

The importance of language in concept learning is widely acknowledged by American (Bruner, 1964) and Russian (Vygotsky, 1962) psychologists. Having the labels of concepts enables individuals to think in symbols rather than in images and to attain other concepts through language experiences in the absence of perceptible instances. Carroll (1964), as noted earlier, has outlined the close relationships among concepts, meanings, and words. However, the purpose here is not to deal with the relationships between language and concept learning, but to show at what points labels may be learned and associated with the various levels of concepts.

Figure 1 indicates that a concept label may be associated with an instance of the concept at any of the four levels--concrete, identity, classificatory, or formal. For example, Billy might manifest a sequence

like this: Billy first encounters a dog. Billy's mother points to the dog and says "dog." Billy then says "dog," and associates the name with his concrete concept of the dog. Next, Billy develops the concept of the same dog at the identity level through experiencing it in different locations and situations. His mother repeats the name at various times in the presence of the dog; Billy says the word repeatedly. The word "dog" now comes to represent Billy's concept of the dog at the identity level. Subsequently, Billy encounters other dogs and observes that they, too, are called "dogs." He generalizes the different dogs as equivalent in some way and associates the name "dog" with whatever similarities he has noted. The word thus comes to represent his class of things called "dogs." At the formal level, with greater maturity, Billy discriminates and learns the societally accepted attributes of the class of things called "dogs" and also learns the names of the attributes. Now Billy's concept of dog approaches or becomes identical to the societally accepted definition of the word "dog." As Carroll (1964) pointed out, the concepts held by individuals and the meanings of the words representing the concepts are the same for mature individuals who share similar cultural experiences and the same language.

In connection with language and concept attainment, we recognize that deaf individuals and others who lack normal speech development may attain concepts at the formal level. By our definition, the individual must know the defining attributes of the concept and must be able

to communicate this knowledge. Verbalizing is normally used in this kind of communication. Other types of symbolic communication, for example, sign language, may also be employed. Speech, per se, is not necessary for the attainment of concepts, but some means for symbolizing and communicating the concept in the absence of examples is necessary at the formal level.

CONCEPT EXTENSION AND UTILIZATION

The individual who has formed a concept may extend and use it as shown in Figure 1. As noted earlier, a concept attained only to the concrete or identity level may be used in solving simple perceptually-based problems. Concepts learned at the classificatory and formal levels can be used in generalizing to new instances, cognizing supraordinate-subordinate relationships, cognizing cause-and-effect and other relations among concepts, and in solving problems.

Ausubel (1963) and Gagné (1966, 1970) have theorized concerning the use and extension of attained concepts; however, very little empirical research has been done. In this regard Ausubel (1966) formulated the constructs of cognitive structure, advance organizer, correlative subsumption, and derivative subsumption to show how previously attained and newly encountered concepts are related, while Gagné has indicated that attained concepts are prerequisite to the learning of rules.

Generalizing to New Instances and Discriminating Noninstances

The attainment of concepts at the classificatory and formal levels reduces the need for additional learning and relearning, primarily

because the individual is able to generalize to new instances of a concept and to discriminate noninstances. Having a concept also provides individuals with expectations which help them deal effectively with new instances of it. Once persons identify a plant as poison ivy, they treat it gingerly. One test of concept attainment in our experiments is the individual's ability to properly categorize instances not previously encountered as instances or noninstances of the particular concept. We find that both school children and collegeage students generalize to new instances readily. Furthermore, the use of instances and non-instances in instructional materials to teach concepts can be manipulated so that errors of overgeneralization and undergeneralization can be reduced (Feldman, 1972; Swanson, 1972).

Not only does having a concept enable learners to identify new instances and act appropriately toward them, but direct and verbal experiences with the new instances possibly increase the validity and power of the concept for the individual. For example, the Canadian visiting Kenya during January, when it is summer there, may attain more valid and powerful concepts of flower and plant. Similarly, by being told that a whale is a mammal, an individual comes to realize that mammals can live in the water as well as on land. Hence, the individual's concept of mammal has greater validity.

Cognizing Supraordinate-Subordinate Relationships

Besides generalizing to new instances, individuals can also use their concepts attained at the formal level, and possibly at the

classificatory level, in cognizing coordinate, supraordinate, and subordinate relationships among classes of things. The lowest level of cognizing these relationships is inferred when persons, according to verbal instructions, put instances of concepts in their proper groups. For example, upon request persons put all instances of red and blue equilateral triangles and of right triangles in a grouping of triangles, and all instances of triangles and of rectangles in a grouping of polygons. Furthermore, they justify each group formed on the basis of the defining attributes of the group. For example, they state that equilateral triangles include all the triangles that have three equal sides, triangles include all the polygons that have three sides, and polygons include all the closed, planar figures that have three or more sides. More precise terminology might be required such as "an equilateral triangle is a simple, plane, closed figure with three sides of equal length."

Possible higher levels of attaining the supraordinate-coordinate-subordinate relationships include what Kofsky (1966) designated as the "whole is the sum of the parts" and "some but not all." Again, merely being able to group a few instances properly according to verbal instructions is not a sufficient test of cognizing the sets of relationships; an adequate justification for the actions is required. According to Kofsky (1966), knowledge concerning supraordinate-subordinate relationships increases with age.

The understanding of supraordinate-subordinate relationships

increases the validity and usability of the individual's concepts. For example, knowing the attributes of acid and also knowing that vinegar is an acid leads to the inference that vinegar has the attributes of all acids, as well as the attributes peculiar to vinegar. Thus all of the things known about acids--for example, how they react with bases--are true for vinegar also. In this way, learning that acid is a concept supraordinate to vinegar increases the validity and usability of tne concept of vinegar for the individual.

Cognizing Other Relationships

There are other statements of relations between or among concepts that are different from relations among supraordinate and subordinate concepts. These additional statements, often termed principles, have been classified by Klausmeier, Ghatala, and Frayer (1974) according to the type of relation that is stated:

1. Cause and effect relationships are statements that may also be expressed in terms of an "if-then" relationship. For example, "tuberculosis is caused by the organism Myobacterium tuberculosis"; "contact with a hot stove produces a blister."

2. Probability statements are principles that express numerically the likelihood of an event's occurrence. For example, "the probability of giving birth to a boy during any given pregnancy is .52"; "provided the coin is fair, the probability of getting a head on only one toss of the coin is .50."

3. Correlational statements describe a relation, often expressed numerically, between two or more objects or events. For example, "If height and weight are measured for a large number of people, the resulting correlation between the two measures is around .50"; "the incidence of lung cancer in women is increasing and the number of women smoking cigarettes is increasing."

4. Axiomatic statements, the most inclusive type of principle, are universally accepted, self-evident truths. Five subclasses have been identified by Bernard (1975): (a) fundamentals, or principles essential to a science, religion, philosophy, or art; (b) laws, or statements of relationship of phenomena that always hold true; (c) rules, or principles in various subject matter domains that prescribe usage, procedure, or conduct; and (d) theorems and (e) axioms, both of which are usually mathematical statements of a relation to be proved or already proved.

Marx (1970) has referred to cause-and-effect, probability, and correlational statements as laws. Gagné (1970) has called these same types of statements principles or rules. In discussing rule learning, Gagné proposed two schemes for classifying rules. The first, based on rule content, divides rules according to those in which the rule relates concepts and designates ideas in contrast to those in which the content functions to guide the individual's response in a specific situation. The second scheme of classification for rules is based

on rule structure--either simple or complex. The most simple rules consist of two concepts, arranged in a chain, in the form "if A, then B." Complex rules consist of a larger number of concepts which are often abstract and require subtle discriminations.

Although the various types of statements that express relations among concepts have been classified in slightly different ways by different experts, it is agreed that understanding these statements is critical to thinking and reasoning. Understanding statements of cause and effect or probability, for example, enables the individual to predict consequences from known conditions and to explain newly encountered phenomena. Bruner et al. (1956) have pointed out that understanding lawful relationships between or among concepts permits classes of things, rather than isolated, individual things, to be related. Gagné (1970) has suggested that the structurally simple rule "round things roll" is the kind of rule young children learn very early because it consists of concrete concepts having clearly perceptible instances. Once learned, this rule enables the child to predict what will happen to all spherical objects under certain conditions. Or, consider the more complex relationship: "When two substances at different temperatures come into contact, the temperatures of the substances tend to equalize." This relationship permits us to infer what will happen is such diverse situations as putting ice cubes in warm soda pop or being lost in a snowstorm.

In all cases, of course, being able to understand and use a lawful

relationship is contingent upon knowing the concepts embedded in the statement. Only then can the rule or axiom or principle be understood and applied to appropriate phenomena.

Using Concepts in Problem-Solving Situations

Problem-solving ability is treated by Klausmeier (in press) as one of the most critical of all outcomes of education; a person who is capable of solving problems can learn independently. A considerable amount of instruction is directed toward teaching students problem-solving skills, and students acquire considerable knowledge through problem solving. Concept learning itself may be regarded as a special case of problem solving.

A situation requiring problem solving is encountered when an individual must respond but does not have immediately available the specific information, concepts, principles, or methods to arrive at a solution. To solve any problem the individual must think adaptively; more specifically, the individual must selectively recall important concepts, principles, and methods needed to solve the problem. Thus, not only may one or more concepts be instrumental in the solution of many kinds of problems, but the more experience an individual has with a given concept, the greater the probability of solving successfully a problem involving that concept.

Much of the organized knowledge concerning the nature of problem solving has been summarized in diverse theories, descriptions of the steps in problem solving, and descriptions of the internal and external

conditions of learning. Although varying slightly in their emphases, these theories and descriptions all attest to the importance of problem solving in complex learning and thinking. In turn, theorists have also focused on the role played by concepts in problem solving. For example, Woodruff (1967) has discussed the role of concepts in higher-level mental activities, including problem solving. In accord with his cumulative model of learning, Gagné (1970) has viewed concepts as prerequisite to the learning of rules, and rules as prerequisite to the solving of problems. Gagné has also indicated that one way in which concepts are called into play in solving problems is by the application of principles to the problem-solving situation. For example, principles underlying the concepts of pressure, volume, gravity, and distance can be utilized to determine the height of a mountain by using a barometer.

ADDITIONAL FEATURES OF THE CLD MODEL

The CLD model is more heavily oriented toward learning than toward development in that it implies that all the concepts held by any individual are learned; they do not emerge simply with maturation. In this context it is similar to four theories of concept learning generated by American experimental psychologists and reviewed by Bourne, Ekstrand, and Dominowski (1971): theory of associations (Bourne & Restle, 1959); theory of hypotheses (Levine, 1966; Trabasso & Bower, 1968); theory of mediation (Osgood, 1953); and theory of information processing

(Hunt, 1962). Also, in agreement with these theories, the model specifies that the attainment of concepts is potentially explainable in terms of principles of learning. Despite some differences in terminology, the CLD model, like Hunt's, represents an information-processing approach to learning. The CLD model differs from the four theories just mentioned in that it describes different levels in the attainment of the same concept and specifies the operations essential to attaining concepts at the successively higher levels. While some of the operations are postulated to be common to more than one level, these operations at the successively higher levels are carried out on more highly differentiated and abstracted properties of actual concept instances or on verbal descriptions of instances and attributes.

The CLD model is similar to Gagné's (1970) cumulative learning model in that both provide a framework for studying the internal and external conditions of learning. It also differs in two regards. Whereas Gagné describes seven forms of learning, ranging from the simplest learning through rule learning and problem solving, in the CLD model only one form of learning, concept learning, is analyzed according to its several constituent cognitive behavirors at each of four levels. Gagné also postulates a linear vertical learning hierarchy extending from signal learning through problem solving. The CLD model, as shown in Figure 1, indicates that a concept when learned at the classificatory or the formal level may be used in cognizing supraordinate-subordinate relations among the concept and other attained

concepts, in understanding relations among concepts such as those incorporated in principles and laws, and in problem solving. Thus, the CLD model departs from the straight linear learning hierarchy postulated by Gagné.

Possibly different from the preceding learning theories and more in agreement with Piaget (1970), the CLD model presumes that the new operations at each successive level involve qualitative changes in operating on instances and attributes of concepts, not merely additions to or modifications of prior operations. Further, the operations that continue from one level to the next are carried out on more highly differentiated and abstracted concept attributes. While the model does not postulate a stage concept associated with age levels as does Piaget, qualitative differences in thinking of the kinds pointed to by Bruner, Olver, Greenfield et al. (1966) and Kagan (1966) are recognized. Also, Bruner's (1964) conceptualization of enactive, iconic, and symbolic representation is accepted as a satisfactory global explanation of how experiences are represented and stored.

The roles of language and directed learning experiences are recognized as being of central importance in attaining concepts at the classificatory and formal levels. The cross-cultural studies of Bruner et al. (1966) support the directed-experiences point of view (cf. Goodnow, 1969). Also, Bruner's (1964) intermediate position that specifies how language facilitates thinking, rather than being essential to thinking (Luria, 1961) or being dependent on thought (Inhelder

& Piaget, 1964), appears valid for the present model. Accepting directed experience as critical in concept attainment de-emphasizes a maturational readiness viewpoint, such as that expressed by Gesell (1928, 1945). While it is accepted that certain cognitive operations emerge with educational experience, this conception does not espouse a behaviorist-environmentalist point of view regarding learning to the extent that either Gagné (1970) or Staats (1971) does.

II

PURPOSES AND METHODS OF THE STUDY

The purpose of this chapter is to provide some perspective regarding the role of the first longitudinal study in a comprehensive study of children's conceptual development during the school years. The plan of the entire longitudinal research precedes a description of the specific purposes of the present study, the specific predictions which are evaluated, and the research design.

OVERVIEW OF THE LONGITUDINAL STUDY OF CHILDREN'S CONCEPTUAL DEVELOPMENT

The primary objective of the longitudinal research is to chart the conceptual development of children from about age 5 to 18. This goal will be accomplished primarily from analyses of longitudinal data that are collected once each year over a period of four years. Data are obtained from four concept assessment batteries constructed within the framework of the CLD model [CLD Assessment Series I: Equilateral Triangle (Klausmeier, Ingison, Sipple, & Katzenmeyer, 1973); II: Cutting Tool (Klausmeier, Bernard, Katzenmeyer, & Sipple, 1973); III: Noun (Klausmeier, Ingison, Sipple, & Katzenmeyer, 1973); and IV: Tree (Klausmeier, Marliave, Katzenmeyer, & Sipple, 1974)]. The rationale and strategy for this programmatic research on children's conceptual learning and development from preschool to the high school years have been outlined in an earlier paper

Hooper and Klausmeier (1973). The theoretical framework for the study reported in this paper is the CLD model which has been described in Chapter I.

The present report, based on the first and second years of assessment during the longitudinal study, is the first reporting of longitudinal findings from the larger program. Performances of children from four grade groups are evaluated from first to second years of assessment in order to obtain information about the course of children's conceptual development. Longitudinal performance is evaluated on CLD Assessment Series I: Equilateral Triangle. Evaluation is in terms of several predictions derived from the CLD model.

The Strategy for the Longitudinal Assessment

The plan of the longitudinal investigation is to study a sample of children from four age groups at four consecutive times during slightly more than three calendar years. The grade groups at the time of first-year assessment in 1973 were kindergarten, third, sixth, and ninth. Each group was tested again in the spring of 1974 and 1975; the final assessment will occur in the spring of 1976. Thus, over three calendar years data will be gathered that include the entire age range of 5 to 18 years with 100 percent overlap of the first and final assessments for the four age groups.

Essential control groups were incorporated in the longitudinal design in one school district to permit an evaluation of: (1) cohort differences (i.e., performance differences in children of the same chronological age but differing in year of birth) and (2) possible confounding effects commonly associated with long-term repeated-measurement designs. In the

present instance a variation of the Campbell and Stanley (1963) posttest only control group design has been employed to evaluate the role of repeated test administrations. Since the design did not provide for the disentanglement of the effects of repeated testing and selective drop-out special attention will be directed toward the possible changing characteristics of the surviving core longitudinal samples.

Sampling Design of the Longitudinal Study

Selective sampling problems and the associated constraints upon external validity are difficult to avoid in any investigation of the present type. While generalization of the resultant developmental norms will obviously be confined to similar age-grade levels and demographic classifications, attempts were made to ensure representative sampling among classes within two different school populations.

The target field locations for the longitudinal study were Watertown, Wisconsin, and Beloit, Wisconsin. The public schools of Watertown provided the locale for the initial tryout and validation of the CLD model assessment batteries related to the concepts of equilateral triangle, cutting tool, noun, and tree. Children of the four grade groups (kindergarten, third, sixth, and ninth grades) that participated in these studies will also be followed for each of the successive years.

The Watertown and Beloit studies comprise a simultaneous replication of the longitudinal study. Beloit was designated as the major source of longitudinal data, however, because its population better reflects the distribution of socio-economic levels in the U.S. The overall sampling design for the research in Beloit is shown in Table 1. The Watertown

TABLE 1

SAMPLING DESIGN FOR THE CLD TESTS

Cohort	1973		1974		1975		1976	
1967	6* (N = 100	→	7	→	8	→	9	
1968	[Kindergarten]		6	40 →	7**	→	8**	(Cohort effect group)
1967			7					
1969					6**	→	7**	
1967					8**			
1970							6**	
1967							9	(Test effect group)
1964	9 (N = 100)	→	10	→	11	→	12	
1965	[Third Grade]		9	→	10*	→	11**	
1964			10					
1966					9**	→	10**	
1964					11**			
1967							9**	
1964							12	
1961	12 (N = 100)	→	13	→	14	→	15	
1962	[Sixth Grade]		12	→	13**	→	14**	
1961			13					
1963					12**	→	13**	
1961					14**			
1964							12**	
1961							15	
1958	15 (N = 100)	→	16	→	17	→	18	
1959	[Ninth Grade]		15	→	16**	→	17**	
1958			16					
1960					15**	→	16**	
1958					17**			
1961							15**	
1958							18**	

*Table entries are approximate mean ages.

**These groups will not be continued if cohort and practice effects are not found after the first year. If effects are found, decisions about continuing will be made after data are analyzed.

sample included smaller numbers of children at each grade and no control groups.

Objectives of the Longitudinal Study

The major data analyses have utilized the longitudinal, as well as cross-sectional, assessments under the following general guidelines. The cross-sectional data collections permit the specification of relative task difficulties and the suggestion of the probable order of acquisition of these concept domains. The longitudinal data collections enable us to (a) specify the order of attainment of the various levels and uses of concepts by children in the various grades of the two school districts, (b) describe the form of the developmental curve for each level of attainment, concept use, and vocabulary acquisition, from first partial attainment through final full mastery; (c) relate the mastery of each level to the mastery of each use, and to vocabulary development.

Thus, the primary objectives of the longitudinal study were (a) to chart the course of children's attainment of selected concepts in various subject fields during their school years, (b) to chart the course of children's uses of the same concepts during their school years, (c) to chart the course of children's development of crucial terminology related to the selected concepts, and (d) to relate the three preceding areas of development. The general propositions and more specific predictions pertaining to these objectives are treated later in this chapter.

Other goals of the longitudinal study, cross-sectional studies, and various controlled experiments were as follows: (a) to determine more explicitly the internal conditions of learning associated with children's mastery of the various levels of concept attainment and their uses, (b) to

determine more explicitly the external conditions of learning that facilitate children's attainment and use of concepts in school settings, (c) to relate children's performances on the four CLD batteries dealing with equilateral triangle, cutting tool, noun, and tree, (d) to relate children's levels of conceptual development as assessed by CLD model batteries to their school achievement in various subject matters, and (e) to validate the CLD model in terms of its robustness in providing a framework for research in concept learning, concept development, and related instruction.

DESIGN OF THE FIRST-YEAR LONGITUDINAL STUDY

The first longitudinal study examined performances of children administered CLD Assessment Series I: Equilateral Triangle. This was the only assessment battery on which the same children were tested for two successive years: 1973 and 1974. Other assessment batteries were either administered for the first time in Beloit in 1974 (i.e., CLD Assessment Series III: Noun and IV: Tree) or else were modified extensively for the 1974 administration (i.e., CLD Assessment Series II: Cutting Tool). Longitudinal evaluation of children's performances on the three remaining CLD batteries, as well as on the equilateral triangle battery, will therefore be the focus of future longitudinal reporting.

The present study utilized data from the initial data collection in 1973 when 400 children, 100 from each of four grades, kindergarten, third, sixth, and ninth, participated. At the time of the second assessment in 1974 these same children were, of course, first, fourth, seventh, and tenth graders. By the second year of assessment, however, normal sources of subject attrition left a surviving longitudinal core group of 351 children,

with the number of children in each grade varying slightly. Focus of the present study was on the performances of these 351 children administered the equilateral triangle battery initially in 1973 and again in 1974.

An additional group of 275 children from Watertown, Wisconsin, was also administered the equilateral triangle battery during the same two successive years. Longitudinal performances of these children were examined and will be reported briefly in Chapter IV.

Purposes of the Study

The CLD model embodies three major propositions. Related to each proposition there are several specific predictions. These major propositions and the related predictions concern hypothesized patterns of children's conceptual learning and development. The purpose of the present study was to test these predictions, thereby clarifying presumed sequencing in conceptual development.

A. Many concepts are attained in an invariant sequence according to four successive levels: concrete, identity, classificatory, and formal. Each level is presumed to be increasingly difficult to attain because of the new operations which are essential to attaining the particular level. It is further presumed that to attain a concept at any particular level an individual must be capable of all of the operations at that level and at the prior level and must also have attained the particular concept at the prior level. These, then, are the prerequisite internal conditions for attaining each consecutive level.

The major proposition also indicates that many, but not necessarily all, concepts are attained in an invariant sequence. Three conditions are essential for concepts to be attained according to the invariant sequence.

First, many actual instances or readily constructed instances are present in the immediate environment that children experience. Second, the child must have experiences with the actual instances or the representations thereof starting early in chi'dhood. Finally, the child must be developing normally, free of severe handicaps of speech, language development, brain injury, etc.

The specific predictions tested in the present longitudinal study were as follows:

1. Children in all grade groups will conform consistently to five acceptable patterns of mastery of the four concept levels during each year of longitudinal assessment. These acceptable patterns are to (a) fail all four levels (FFFF), (b) pass the concrete and fail the next three levels (PFFF), (c) pass the concrete and identity levels but fail the next two levels (PPFF), (d) pass the first three levels but fail the formal level (PPPF), and finally, (e) pass all four levels (PPPP).
2. (a) Retesting in the longitudinal assessment will not have a significant influence on number and proportion of children conforming to predicted patterns.
   (b) Cohort differences will not have a significant influence on number and proportion of children of any specific age conforming to predicted patterns.
3. (a) Retesting in the longitudinal assessment will not have a significant influence on the number and proportion of children attaining each of the four concept levels.

(b) Cohort differences will not have a significant influence on the number and proportion of children of a specific age who fully attain each of the four concept levels.

4. In accord with the invariant sequence prescribed by the model, a child will master a concept at the same level as the previous year or at higher levels of attainment in the sequence.

B. Concepts attained to various levels may be used in (a) cognizing supraordinate-subordinate relationships in a hierarchy or taxonomy where the attained concept is an element of the hierarchy or taxonomy, (b) in understanding principles that state a relationship between the attained concept and one or more other concepts, and (c) in solving problems that require use of the particular concept. The specific predictions which follow from the preceding proposition and which were tested in the present study were as follows:

5. Children who attain a concept to only concrete and/or identity levels by year 2 will only be able to use that concept in understanding simple perceptual problems.

6. (a) A higher proportion of children who fully attain the formal level by year 2, in comparison with those whose highest level of attainment by year 2 is classificatory, will fully master each of the three concept uses.

(b) More specifically, a higher proportion of children whose highest level of attainment was at classificatory year 1 and who attain to formal year 2 will master each of the three concept uses when compared to those children whose highest level of attainment is classificatory year 1 and year 2.

7. (a) Retesting in the longitudinal assessment will not have a significant influence on the number and proportion of children who master each of the three concept uses.

   (b) Cohort differences will not have significant influence on the number and proportion of children of a specific age who master each of the three concept uses.

8. Compared to performance of the previous year, children will either gain or remain stable on mastery of each of the three concept uses.

C. Having the labels of the concept and its attributes (a) facilitates attainment of the concept at the classificatory level and possibly the other levels, (b) is requisite for attaining the concept at the formal level, and (c) facilitates mastery of the three uses of the concept. This proposition emphasizes the importance of language in attaining concepts at the classificatory and the formal levels and also in being able to use the concept in various ways.

The two specific predictions related to this proposition which were tested in the present study may be stated as follows:

9. As each grade group is followed during longitudinal assessment, percentage of vocabulary items correct will increase.

10. Children in each grade group gaining in number of vocabulary items passed compared to the previous year, will also gain in number of uses items passed, compared to the previous year.

Assessment Batteries Used in the Longitudinal Research Program

In addition to the usual criteria of reliability, objectivity, and usability, several others also guided development of CLD Assessment Series I: Equilateral Triangle; II: Cutting Tool; III: Noun; and IV: Tree.

First, the materials and instructions had to permit assessment of subjects of preschool through high school age. It was presumed that not all subjects of preschool age would attain a given concept at the concrete level and that not all high school subjects would attain it at the formal level. Second, to test for attainment at the concrete, identity, and classificatory levels the particular concept selected had to have perceptible instances or representations thereof. Third, the concept had to be definable by publicly accepted attributes in order to test attainment at the formal level. (It should be noted that many concepts are definable in terms of attributes even though this method of definition is often not used, even in unabridged dictionaries.) Fourth, the concept selected for a battery should be relatable to the subject matter which pupils encounter in school. This is in keeping with the supposition that directed experience, including instruction in school, is a powerful determinant of the particular concepts attained by individuals and also of their level of attainment and use. Further, since much instruction in school deals with concepts, the CLD model should be applicable to the design of instruction, and the subtests, when fully validated, should be usable in assessing the level of conceptual development in school-age children. Fifth, the particular concept had to be part of a taxonomy in order to test its use in cognizing supraordinate-subordinate relationships. Finally, the concept had to be usable in cognizing principles and in problem solving. (A concept may be usable in solving simple problems that can be solved on a perceptible basis without being used first in understanding a principle, or it may be used first in understanding a principle and then in solving more complex problems.)

To develop the tests of concept attainment and utilization, the behaviors involved in attaining the concept were analyzed and then test

items and administrative procedures to assess the behaviors were developed. A subtest was developed to assess each of the four levels of concept attainment. Each subtest was constructed specifically to assess the particular operations involved in attaining a concept at each of the four levels. A subtest was also developed to ascertain the extent to which a child could apply the concept in each of the three uses that have been described. Thus, for the present study, which used only CLD Assessment Series I: Equilateral Triangle, a total of 7 subtests was developed. All subtests were designed as paper and pencil tasks that could be group administered.

Items within the concrete, identity, and classificatory levels were constructed to be more difficult as nonexamples (a) increased in number and (b) shared more defining and/or variable attributes with the target examples. Specific information regarding the exact number of items used in each subtest of battery is available in Table 5, which is included in the next chapter presenting results of the longitudinal assessment of equilateral triangle. All test items went through expert review and empirical validation while under development.

Participating Children

Longitudinal core groups. Three hundred and fifty-one children from Beloit comprised the primary longitudinal sample for the present study. Eighty-two kindergarten, 92 third-grade, 91 sixth-grade, and 86 ninth-grade children were tested in both 1973 and 1974. The number of boys and girls tested in each grade was either equal or very close. In the second year of assessment these same children were, of course, first, fourth, seventh, and tenth graders.

Two hundred and seventy-five children from Watertown also participated in the first and second years of longitudinal study. Forty-eight kindergarten,

71 third-grade, 78 sixth-grade, and 78 ninth-grade children took part in the longitudinal Watertown study during 1973 and 1974 assessments.

The schools and classrooms in which the children in Beloit and Watertown were enrolled were judged typical of the particular school system and also of a large number of classrooms in small cities in Wisconsin. The Beloit subject population is described in greater detail in Chapter III.

Control groups. Control groups were used only in the Beloit longitudinal data collection. The control group to assess any positive or negative effects of retesting was composed of 160 children (of the same ages and grades as children in the second year of the longitudinal core group) tested in 1974 and randomly selected from the same schools as the 351 children in the Beloit longitudinal core group. Forty first graders, 40 fourth graders, 40 seventh graders, and 40 tenth graders composed the control group for retesting effects. Equal numbers of boys and girls were included at each grade. The control group for retesting effects is described in greater detail in Chapter III.

The cohort control group was composed of 160 children (of the same ages and grades as children in the first year of the longitudinal core group) tested in 1974 and also randomly selected from the same schools as the 351 children in the Beloit longitudinal sample. Forty children from each of four grades, kindergarten, third, sixth, and ninth, composed this control group. Equal numbers of boys and girls were included at each grade. The cohort control group is described in greater detail in Chapter III.

Data Collection

The appropriate subtests of the battery were administered to groups of 20 to 30 children with the exception of kindergarten and first-grade children. These youngest subjects were tested in small groups of five to eight children in order to reduce distractibility and, in general, to enable the test administrators to supervise the test taking situation more closely. Control group children were also occasionally tested in small groups of six to eight. During the first year of data collection two test administrators, one male and one female, were responsible for testing. During the second year the same male administrator and a new male administrator replacing the female were responsible for data collection. The same administrators also scored the tests and coded the test information for subsequent data analyses.

Treatment of the Data

On each subtest of the equilateral triangle assessment battery a subject was scored as having either passed or failed; that is, results were treated as dichotomous data. Specific criteria for attainment of each subtest determined passing, or attainment of a subtest. These specific criteria for attainment of each subtest will be explained in Chapter III, which presents results of the longitudinal assessment of equilateral triangle for the Beloit sample.

In general, data were quantified by computing frequencies and proportions of subjects at each grade group who attained each concept level and each uses subtest. Certain post hoc statistical tests were used where appropriate to obtain more specific information about differences in frequencies and proportions. In addition, means and standard deviations of items correct on levels and uses subtests were computed for each grade

group during both years of assessment. Each of the specific predictions outlined in this chapter was evaluated in terms of these descriptive and statistical analyses.

III

LONGITUDINAL RESULTS OF CLD ASSESSMENT SERIES I: EQUILATERAL TRIANGLE (BELOIT)

OVERVIEW

A brief description of the child population composing the longitudinal sample (core group), retest control group, and cohort control group precedes a report of the specific criteria for full attainment of each subtest of the equilateral triangle battery. The major portion of this chapter is devoted to descriptive evaluation of the assessment data collected in 1973 and 1974. These longitudinal data are presented and evaluated in terms of the evidence they provide for each of the predictions derived from the CLD model.

CHILD POPULATION

Longitudinal Sample

Table 2 presents a summary description, according to sex and age, of the 351 children who participated in the longitudinal assessment. These data are provided only for year 2; the same information for the longitudinal core, year 1, requires only a subtraction of 12 months. Children in the longitudinal core group will hereafter be referred to as belonging to one of four grade blocks. Block 1 consisted of 82 children tested in year 1 (1973) as kindergarteners and again in year 2 (1974) as first graders. Similarly, in Block 2 there were 92 children, tested as third graders and a

TABLE 2

LONGITUDINAL CORE-YEAR 2: TOTAL NUMBER OF CHILDREN, MEAN AGE AND AGE RANGE AT EACH GRADE GROUP

Grade	Number		Mean Age (in years and months)	Age Range (in years and months)
1	Total	82	6 - 10	6 - 3 to 7 - 4
	Boys	40	6 - 10	6 - 3 to 7 - 4
	Girls	42	6 - 10	6 - 4 to 7 - 4
4	Total	92	9 - 10	9 - 3 to 10 - 8
	Boys	46	9 - 10	9 - 3 to 10 - 7
	Girls	46	9 - 10	9 - 3 to 10 - 8
7	Total	91	12 - 10	12 - 2 to 13 - 8
	Boys	44	12 - 10	12 - 3 to 13 - 8
	Girls	47	12 - 9	12 - 2 to 13 - 5
10	Total	86	15 - 9	15 - 2 to 16 - 7
	Boys	43	15 - 9	15 - 3 to 16 - 7
	Girls	43	15 - 8	15 - 2 to 16 - 5

year later as fourth graders. In Block 3, 91 children participated (as sixth graders year 1 and as seventh graders year 2) and in Block 4, 86 children took part (as ninth graders and again as tenth graders). Table 2 shows that number of boys and girls in each block was equal in Blocks 2 and 4 and very close in Blocks 1 and 3. The age range of the children within each grade varied from 13 months in Block 1 to 18 months in Block 3. Mean ages of boys and girls within grades were very close.

Retest Control Group

Table 3 presents number of children in each grade of the retest control group, as well as mean age and age range. The retest control group children were, of course, in the same grades as children in year 2 of the longitudinal core group: first, fourth, seventh, and tenth grades. Comparison of age data in Tables 2 and 3 shows that these control group children and core group children in the second year of the longitudinal study were identical or very close. The age range of the children in the retest control group varied from 13 months for the first graders to 18 months for the tenth graders. Mean ages of the 20 boys and 20 girls within each of the grade groups varied only slightly.

Cohort Control Group

Table 4 presents number of children in each grade of the cohort control group and their mean ages and age ranges. The cohort control group children tested in year 2 were in the same grades as children in year 1 of the longitudinal sample: kindergarten, third, sixth, and ninth grades. Age range of children in the cohort control group varied from 11 months for the kindergarteners to 19 months for the ninth graders. Mean ages of the 20 boys and 20 girls within each grade varied little. Comparison of Tables 2

TABLE 3

RETEST CONTROL: TOTAL NUMBER OF CHILDREN, MEAN AGE AND AGE RANGE AT EACH GRADE GROUP

Grade	Number		Mean Age (in years and months)	Age Range (in years and months)
1	Total	40	6 - 9	6 - 4 to 7 - 5
	Boys	20	6 - 10	6 - 4 to 7 - 5
	Girls	20	6 - 9	6 - 4 to 7 - 5
4	Total	40	9 - 10	9 - 4 to 10 - 6
	Boys	20	9 - 10	9 - 5 to 10 - 6
	Girls	20	9 - 9	9 - 4 to 10 - 5
7	Total	40	12 - 11	12 - 5 to 13 - 7
	Boys	20	12 - 11	12 - 5 to 13 - 7
	Girls	20	12 - 10	12 - 5 to 13 - 4
10	Total	40	15 - 10	15 - 3 to 16 - 9
	Boys	20	15 - 11	15 - 3 to 16 - 8
	Girls	20	15 - 9	15 - 3 to 16 - 9

TABLE 4

COHORT CONTROL: TOTAL NUMBER OF CHILDREN, MEAN AGE AND AGE RANGE AT EACH GRADE GROUP

Grade	Number		Mean Age (in years and months)	Age Range (in years and months)
K	Total	40	5 - 9	5 - 4 to 6 - 3
	Boys	20	5 - 10	5 - 4 to 6 - 3
	Girls	20	5 - 9	5 - 4 to 6 - 2
3	Total	40	8 - 9	8 - 3 to 9 - 8
	Boys	20	8 - 10	8 - 4 to 9 - 4
	Girls	20	8 - 9	8 - 3 to 9 - 8
6	Total	40	11 - 10	11 - 4 to 12 - 5
	Boys	20	11 - 9	11 - 4 to 12 - 5
	Girls	20	11 - 11	11 - 5 to 12 - 5
9	Total	40	14 - 11	14 - 3 to 15 - 10
	Boys	20	15 - 0	14 - 3 to 15 - 10
	Girls	20	14 - 9	14 - 3 to 15 - 5

and 4 shows that children in the cohort control group and children in year 1 of the longitudinal core were closely matched with respect to mean age and age range (age of children in the first year of the longitudinal study may be determined simply by subtracting 12 months from the mean age and age range data presented in Table 2).

Attrition in the Longitudinal Sample

In future sections of the present chapter comparisons will be made between performances of children in the longitudinal sample and in the two control groups. The 40 children in the control group for retesting effects can only be compared with the 351 children who survived for the second year of assessment. The 40 children in the cohort control group can be compared with the 351 children remaining in the longitudinal sample by year 2 if it is determined that the 49 children lost from year 1 to year 2 did not show any strong or systematic performance differences in comparison with the surviving core children. Preliminary analyses compared year 1 performances of the 351 children remaining in the second year of assessment and the 49 children representing the subject loss from year 1 to year 2. Such analysis is important not only for statistical comparisons between cohort control and surviving core group children, but is also an initial step in the continuous monitoring of children who drop out each year of the longitudinal study for any possible selective and biasing characteristics.

From year 1 to year 2, 18 children dropped out in Block 1 (10 boys and 8 girls); 8 children were lost in Block 2 (4 boys and 4 girls); 9 children in Block 3 (6 boys and 3 girls); 14 children in Block 4 (7 boys and 7 girls). Thus, the number of boys and girls lost within grade blocks did not differ

markedly. Information made available to the school system by parents indicated that 26 of the 49 children left Beloit public schools because families moved out of the city. Eighteen left to enter parochial schools; five left for other reasons (e.g., health problems, entry into special schools).

Preliminary Chi-square analyses were conducted on the first year data to discover if the proportions of the 351 surviving children and the 49 drop-out children attaining each of the four concept levels and three concept uses differed significantly ($p < .05$). No statistically significant differences were found at the kindergarten or ninth grade. In the third grade, two Chi-squares were significant; a greater proportion of surviving core group children than drop-out children attained at the concrete and identity levels (Chi-square = 7.32, concrete; 10.28, identity, d.f. = 1). In the sixth grade, more drop-out children than surviving core group children mastered the problem solving subtest (Chi-square = 4.19, d.f. = 1). Data for surviving and drop-out children combined across grades resulted in no statistically significant differences in performance between the two groups on the four concept levels or three concept uses. Thus, no strong, systematic differences in performance on the levels and uses subtests between the two groups of children were found, indicating that the children who represented the attrition from year 1 to year 2 were lost on a random, rather than on a systematic performance basis.

CRITERIA FOR FULL ATTAINMENT

As noted in Chapter I, one test was used for each level of concept attainment and one test for each concept use. Criteria were established

for determining full attainment of the levels and uses; the criterion established for each subtest was that all items, except one, had to be passed. Table 5 summarizes information describing the seven subtests, including the total number of items in each subtest and the criterion for full attainment of each level and use. For example, eight items were included to assess the concrete level of concept attainment. The criterion for full attainment was set at having seven of eight items correct. The criteria for the other levels of concept attainment and the three uses were similar as may be observed in Table 5. (The model requires two other kinds of items in the assessment of the formal level; however, at the time of the year 1 administration these items had not yet been developed. In year 2, the additional components of the formal subtest were included; however, for the purpose of comparable longitudinal evaluation of performances in 1973 and 1974 it was necessary that the original though incomplete version of the formal subtest be used.) The criteria established for full attainment are especially important; passing the four levels consecutively is considered critical for describing the course of children's conceptual development as presumed by the CLD model.

CONFORMITY TO THE PREDICTED INVARIANT SEQUENCE

Each successive level of concept attainment is postulated by the CLD model to require the use of one or more new cognitive operations. It is hypothesized that each subtest will be more difficult than the previous subtest because it requires the use of an additional cognitive operation. Thus, the CLD model itself constrains the number of acceptable patterns of success and failure for the four concept levels. Five patterns of

TABLE 5

NUMBER OF ITEMS AND CRITERIA DEFINING FULL ATTAINMENT FOR EACH CONCEPT LEVEL AND USE

Subtest	Number of Items	Criteria for Full Attainment
1. Concrete:	8	7 correct
2. Identity:	8	7 correct
3. Classificatory:	3	3 correct
4. Formal		
a. Discriminating Attributes:	3	2 correct
b. Labels:	7	5 correct
5. Principle	5 pairs	4 correct
6. Problem Solving:	5	4 correct
7. Supraordinate-Subordinate:	4 pairs	3 correct

passing and failing the four successive levels of attainment are consistent with the model. These are: to fail all four levels (FFFF), to pass the concrete level and fail the other three (PFFF), to pass both the concrete and identity and to fail the last two (PPFF), to pass the first three levels and fail formal (PPPF), and finally to pass all four levels (PPPP).

Number and Proportion of Each Grade Group in the Longitudinal Sample Conforming to the Model

Table 6 presents the number and proportion of children in each grade of the longitudinal sample who conformed to the predicted sequence of attainment in the first year of assessment. Of the 351 children, 91 percent conformed by following one of the five acceptable patterns. There are 11 patterns that are inconsistent with the model. The bottom of Table 6 presents the number and proportion of core group children, year 1, displaying nonconforming patterns. Thirty children, or nine percent, did not conform during the first year of assessment. Most of the nonconforming children were among the youngest children.

Table 7 presents the number and proportion of children in each grade group of the longitudinal sample who conformed to the predicted sequence of attainment in the second year of assessment. In year 2, 331 of the children, or 94 percent, followed acceptable patterns of concept attainment. Twenty children, or six percent, followed non-acceptable patterns. Of these 20 nonconforming children, 16 fell into the unacceptable PPFP pattern indicating that they met the criterion for attainment of the formal level after failing the classificatory level. The conforming data provide some initial support for the first prediction which calls for children to follow one of the five acceptable patterns of mastery of the four concept levels. A more precise

TABLE 6

LONGITUDINAL CORE-YEAR 1: NUMBER AND PROPORTION OF FOUR GRADE GROUPS CONFORMING AND NOT CONFORMING TO PREDICTED SEQUENCE OF ATTAINMENT

Pass-Fail Sequence	K (n = 82)	3rd (n = 92)	6th (n = 91)	9th (n = 86)	All Grades (N = 351)
FFFF	3 .04	0 .00	0 .00	0 .00	3 .01
PFFF	5 .06	2 .02	0 .00	0 .00	7 .02
PPFF	36 .44	17 .18	4 .04	0 .00	57 .16
PPPF	22 .27	52 .57	42 .46	16 .19	132 .38
PPPP	0 .00	12 .13	41 .45	69 .80	122 .35
Subtotal Conforming	66 .80	83 .90	87 .96	85 .99	321 .91
FFFP	0 .00	0 .00	0 .00	0 .00	0 .00
FFPF	4 .05	0 .00	0 .00	0 .00	4 .01
FFPP	0 .00	0 .00	0 .00	0 .00	0 .00
FPFF	6 .07	0 .00	0 .00	0 .00	6 .02
FPFP	0 .00	0 .00	0 .00	0 .00	0 .00
FPPF	2 .02	4 .04	0 .00	0 .00	6 .02
FPPP	0 .00	0 .00	0 .00	0 .00	0 .00
PFFP	0 .00	0 .00	0 .00	0 .00	0 .00
PFPF	4 .05	2 .02	0 .00	0 .00	6 .02
PFPP	0 .00	1 .01	0 .00	0 .00	1 .00
PPFP	0 .00	2 .02	4 .04	1 .01	7 .02
Subtotal Not Conforming	16 .20	9 .10	4 .04	1 .01	30 .09

TABLE 7

LONGITUDINAL CORE-YEAR 2: NUMBER AND PROPORTION OF FOUR GRADE GROUPS CONFORMING AND NOT CONFORMING TO PREDICTED SEQUENCE OF ATTAINMENT

Pass-Fail Sequence	1st (n = 82)	4th (n = 92)	7th (n = 91)	10th (n = 86)	All Grades (N = 351)
FFFF	4 .05	0 .00	0 .00	0 .00	4 .01
PFFF	1 .01	0 .00	0 .00	0 .00	1 .00
PPFF	21 .26	10 .11	5 .05	4 .05	40 .11
PPPF	47 .57	50 .54	27 .30	9 .10	133 .38
PPPP	6 .07	25 .27	52 .57	70 .81	153 .44
Subtotal Conforming	79 .96	85 .92	84 .92	83 .97	331 .94
FFFP	0 .00	0 .00	0 .00	0 .00	0 .00
FFPF	0 .00	0 .00	0 .00	0 .00	0 .00
FFPP	0 .00	0 .00	0 .00	0 .00	0 .00
FPFF	0 .00	0 .00	0 .00	0 .00	0 .00
FPFP	0 .00	0 .00	0 .00	0 .00	0 .00
FPPF	1 .01	1 .01	0 .00	0 .00	2 .01
FPPP	0 .00	1 .01	0 .00	0 .00	1 .01
PFFP	0 .00	1 .01	0 .00	0 .00	1 .00
PFPF	0 .00	0 .00	0 .00	0 .00	0 .00
PFPP	0 .00	0 .00	0 .00	0 .00	0 .00
PPFP	2 .02	4 .04	7 .08	3 .03	16 .05
Subtotal Not Conforming	3 .04	7 .08	7 .08	3 .03	20 .06

evaluation of evidence for this prediction, however, will be presented in a later section.

Influence of Retesting and Cohort on Conformity to the Model

Tables 8 and 9 present, in similar fashion, the number and proportion of control group children following acceptable patterns of attainment. In Table 8 it can be seen that of the 160 children in the control group for retesting effects 147, or 92 percent, conformed to the model, whereas 13 children, or 8 percent, failed to conform. Inspection of Table 9 reveals that 91 percent (145 children) of the cohort control group included to assess any unique effects due to year of birth followed one of the five acceptable patterns of attainment and 9 percent (15 children) followed patterns incompatible with the CLD model.

The second prediction presented in Chapter II states that there should be no effects due to retesting and cohort on conformity to acceptable patterns of concept attainment. In order to determine if retesting had a significant influence on the proportion of children conforming to the predicted invariant sequence, Chi-square tests were computed ($p < .05$) between the subtotals of children following acceptable patterns in the retest control group and in the longitudinal core group-year 2, at each grade and for all grades combined. None of the Chi-squares approached statistical significance. It is concluded, therefore, that repeated participation in the longitudinal assessment did not significantly influence conformity to the model.

In order to determine if year of birth had a significant influence on conformity to the model, Chi-square tests were also computed ($p < .05$) between the subtotals of children following acceptable patterns in the cohort

TABLE 8

RETEST CONTROL: NUMBER AND PROPORTION OF FOUR GRADE GROUPS CONFORMING AND NOT CONFORMING TO PREDICTED SEQUENCE OF ATTAINMENT

Pass-Fail Sequence	1st (n = 40)	4th (n = 40)	7th (n = 40)	10th (n = 40)	All Grades (N = 160)
FFFF	3	0	0	0	3
	.08	.00	.00	.00	.02
PFFF	0	1	0	0	1
	.00	.03	.00	.00	.01
PPFF	10	0	4	5	19
	.25	.00	.10	.13	.12
PPPF	22	17	11	3	53
	.55	.43	.28	.08	.33
PPPP	0	21	20	30	71
	.00	.53	.50	.75	.44
Subtotal Conforming	35	39	35	38	147
	.88	.98	.88	.95	.92
FFFP	0	0	0	0	0
	.00	.00	.00	.00	.00
FFPF	0	0	0	0	0
	.00	.00	.00	.00	.00
FFPP	0	0	0	0	0
	.00	.00	.00	.00	.00
FPFF	2	0	0	0	2
	.05	.00	.00	.00	.01
FPFP	0	0	0	0	0
	.00	.00	.00	.00	.00
FPPF	1	0	0	0	1
	.03	.00	.00	.00	.01
FPPP	0	0	0	0	0
	.00	.00	.00	.00	.00
PFFP	0	0	0	0	0
	.00	.00	.00	.00	.00
PFPF	2	0	0	0	2
	.05	.00	.00	.00	.01
PFPP	0	0	0	0	0
	.00	.00	.00	.00	.00
PPFP	0	1	5	2	8
	.00	.03	.13	.13	.05
Subtotal Not Conforming	5	1	5	2	13
	.13	.03	.13	.05	.08

TABLE 9

COHORT CONTROL: NUMBER AND PROPORTION OF FOUR GRADE GROUPS CONFORMING AND NOT CONFORMING TO PREDICTED SEQUENCE OF ATTAINMENT

Pass-Fail Sequence	K (n = 40)	3rd (n = 40)	6th (n = 40)	9th (n = 40)	All Grades (N = 160)
FFFF	3 .08	1 .03	0 .00	0 .00	4 .03
PFFF	4 .10	1 .03	0 .00	0 .00	5 .03
PPFF	11 .28	8 .20	1 .03	4 .10	24 .15
PPPF	15 .38	22 .55	17 .43	9 .23	63 .39
PPPP	0 .00	6 .15	20 .50	23 .58	49 .31
Subtotal Conforming	33 .83	38 .95	38 .95	36 .90	145 .91
FFFP	0 .00	0 .00	0 .00	0 .00	0 .00
FFPF	2 .05	0 .00	0 .00	0 .00	2 .01
FFPP	0 .00	0 .00	0 .00	0 .00	0 .00
FPFF	2 .05	1 .03	0 .00	0 .00	3 .02
FPFP	0 .00	0 .00	0 .00	0 .00	0 .00
FPPF	3 .08	0 .00	0 .00	0 .00	3 .02
FPPP	0 .00	0 .00	0 .00	0 .00	0 .00
PFFP	0 .00	0 .00	0 .00	0 .00	0 .00
PFPF	0 .00	1 .03	0 .00	0 .00	1 .01
PFPP	0 .00	0 .00	0 .00	0 .00	0 .00
PPFP	0 .00	0 .00	2 .05	4 .10	6 .04
Subtotal Not Conforming	7 .18	2 .05	2 .05	4 .10	15 .09

control group and in the longitudinal core group-year 1, for each grade and for all grades combined. Only one of these tests reached statistical significance. A larger proportion of children in the ninth grade of the longitudinal core group followed acceptable patterns compared to the proportion of children in the ninth grade of the control group (Chi-square = 5.60, d.f. = 1). Since there were no systematic findings, we conclude that cohort differences had no substantial influence on conformity to the predicted invariant sequence. The second prediction is clearly supported by both sets of data.

Consistency in Conformity to Predicted Patterns from Year 1 to Year 2

Information presented in Table 10 permits an examination of the contingent relation between conformity to the predicted invariant sequence in the first and second years of longitudinal assessment. These data are critical to an evaluation of the first and major prediction asserting that conformity to the five acceptable patterns will consistently be observed as children are tested longitudinally.

The number and proportion of each grade block following and not following acceptable patterns in year 2 are shown as a function of following and not following acceptable patterns in year 1. (In Appendix A, Table A-1 presents for the entire longitudinal sample a complete contingency matrix for number of children following each of the total 16 patterns during first and second assessments.) For example, Table 10 shows that in Block 1 (referring to the 82 children who were in kindergarten year 1, first grade year 2) 66 children conformed to the model at the time of initial assessment. In year 2, 63 of these children (95 percent) conformed once again; three children did not. Table 10 also shows that in Block 1, 16 children did not conform year 1, whereas in year 2 all of these children followed

TABLE 10

NUMBER AND PROPORTION OF CHILDREN IN EACH GRADE BLOCK CONFORMING AND NONCONFORMING TO PREDICTED INVARIANT SEQUENCE IN 1974 AS A FUNCTION OF CONFORMING OR NONCONFORMING IN 1973

	Conform 1973 (year 1)					Nonconform 1973 (year 1)				
	Block					Block				
	1	2	3	4	Total	1	2	3	4	Total
N =	66	83	87	85	321	N = 16	9	4	1	30
Conform	63	77	80	82	302	16	8	4	1	29
1974 (year 2)	.95	.93	.92	.96	.86	1.00	.89	1.00	1.00	.08
Nonconform	3	6	7	3	19	0	1	0	0	1
1974 (year 2)	.05	.07	.08	.04	.05	.00	.11	.00	.00	.01

acceptable patterns. As another example, we may inspect the data presented for the 86 children in Block 4 (ninth graders year 1, tenth graders year 2). Examination reveals that 85 children conformed the first year of assessment and of these, 82 were consistent in following acceptable patterns the second year. Three of the children who conformed as ninth graders failed to do so as tenth graders. The single child in Block 4 who did not conform year 1 did so year 2. Across all grade blocks, Table 10 indicates that 321 children (91 percent) conformed at the time of the first assessment and 331 (94 percent) followed acceptable patterns at the time of the second assessment. This information duplicates, of course, the subtotals presented in Tables 6 and 7, to which we have earlier referred. Information uniquely disclosed by Table 10 indicates that of the 351 children in the longitudinal sample, 302 or 86 percent consistently conformed to the predicted invariant sequence. Twenty-nine children, or eight percent, did not conform year 1 but did so by year 2. Only one child (from Block 2) did not conform during either the first or second assessments. More problematic are the 19 children (five percent of the total sample) who followed acceptable patterns year 1 but failed to conform year 2. As shown in Table 10, these children were distributed as follows: Block 1, three children; Block 2, six children; Block 3, seven children; and Block 4, three children. Frequencies are thus fairly uniform across blocks.

In order to examine more closely the performances of the 19 children who were nonconformers year 2 and the single child who did not conform either year 1 or year 2, Table 11 presents the specific patterns of exception into which these children fell year 2 and the number of items correct on those subtests for which mastery criterion was not reached. The three children in the unacceptable FPPF and FPPP patterns passed

TABLE 11

FREQUENCIES OF SUBJECTS ACCORDING TO PATTERN OF EXCEPTION YEAR 2 AND ITEMS CORRECT AT EACH CONCEPT LEVEL NOT ATTAINED

N	Pattern of Exception Year 2	Number of Items Correct on Concrete Subtest (7 required)						
		0	1	2	3	4	5	6
2	FPPF						2	
1	FPPP						1	
		Number of Items Correct on Identity Subtest (7 required)						
		0	1	2	3	4	5	6
1	PFFP							1
		Number of Items Correct on Classificatory Subtest (3 required)						
		0	1	2				
16	PPFP	4	3	9				
1	PFFP	1						

five of the eight concrete subtest items, and consequently came close to meeting the criterion for mastery. The single child in the PFFP pattern of exception just barely missed the criterion for mastery of the identity subtest. The majority (16) of the nonconforming children fell into the unacceptable PPFP pattern. Table 11 shows that nine of these children barely missed reaching criterion for attainment of the classificatory level, although four failed all items on this subtest. The single child in the PFFP pattern who came close to mastery of the identity level, as noted above, failed all items of the classificatory subtest but went on to full attainment of formal.

From this detailed examination it is clear that most of the 20 children who were nonconformers year 2 came very close to meeting criterion on subtests that should have been passed according to the CLD model, since higher levels were mastered. Only five of the children, and all of these classificatory level non-attainers, fell far short of meeting criterion. These instances may be explained, at least speculatively, as the results of inattentiveness or carelessness during test-taking. (In Appendix A, Table A-2 presents for children in each block the pass/fail pattern of attainment year 1, year 2, and the exact item performances on subtests not mastered year 2 for each of these 20 noncomforming children. Item performances for both years of longitudinal assessment can be examined.)

Data presented to this point have addressed the prediction of consistent conformity to the five acceptable patterns of mastery of the four concept levels, as well as the expected absence of retesting and cohort effects. To review briefly, it was found that 91 percent of the longitudinal sample conformed to the predicted invariant sequence of concept

attainment at the initial assessment, 94 percent conformed year 2, and 86 percent of the 351 children in the longitudinal sample consistently followed acceptable patterns of concept mastery over both years of assessment. Moreover, data from the retest and cohort control groups confirmed that conformity to the model was not influenced by repeated testing in the longitudinal assessment nor by any special or unique effects due to the core group's year of birth. The longitudinal data collected over a two year span strongly support the prediction of conformity to the invariant sequence prescribed by the CLD model.

LONGITUDINAL ATTAINMENT OF THE FOUR CONCEPT LEVELS

The present section will examine in detail attainment of each of the four concept levels during each year of assessment, especially as it reflects changes in children's conceptual development. The first question addressed in this section relates to the third prediction: retesting and cohort are not expected to influence attainment of the four concept levels. Next, we consider longitudinal attainment of concept levels in conjunction with conformity to the five acceptable patterns of attainment. Finally, we examine the data relating to highest level of concept attainment at the time of initial assessment in comparison with highest level of concept mastery the following year. These latter data provide longitudinal information regarding age changes in conceptual development and address the fourth prediction: children should master the equilateral triangle concept at a higher level than the previous year or, equally acceptable, at the same level as the previous year. This prediction is, of course, critical to the invariant sequence prescribed by the model.

Influence of Retesting and Cohort on Full Attainment of the Four Concept Levels

Table 12 presents the number and proportion of children in each grade of the longitudinal core-year 2, and in each grade of the retest control group attaining each of the levels. For example, of the 82 first graders in the second year of assessment 93 percent fully mastered concrete; 94 percent, identity; 66 percent, classificatory; and 10 percent, formal. Of the 40 first-grade children in the retest control group the percentages attaining each of the levels were 85 percent, concrete; 88 percent, identity; 63 percent, classificatory; and 0 percent, formal. The data are also provided for all children combined and indicate mastery performances that are very comparable for children who were administered the assessment battery twice and for the control children who took the battery for the first time during the second year of longitudinal assessment.

Chi-square tests were performed in order to determine if any statistically significant differences ($p < .05$) occurred in numbers of core and retest control group children attaining each concept level within each grade and for all grades combined. Within grade, only two of the 16 Chi-squares reached statistical significance. A larger number of first grade core group children than control group children attained the formal level (Chi-square = 4.18, d.f. = 1). Among fourth graders, however, more control group than core group children attained the formal level (Chi-square = 5.27, d.f. = 1). Since statistically significant findings were few and non-systematic, it is concluded that repeated participation in the longitudinal assessment had no consistent biasing influence on attainment of the four concept levels.

TABLE 12

NUMBER AND PROPORTION OF CHILDREN IN EACH GRADE GROUP THAT FULLY MASTERED EACH LEVEL OF CONCEPT ATTAINMENT: COMPARING CORE GROUP-YEAR 2 AND RETEST CONTROL

Grade Group	Concrete	Identity	Classif.	Formal
1st				
Core-Year 2	76	77	54	8
(n = 82)	.93	.94	.66	.10
Retest	34	35	25	0
(n = 40)	.85	.88	.63	.00
4th				
Core-Year 2	90	91	77	31
(n = 92)	.98	.99	.84	.34
Retest	40	39	38	22
(n = 40)	1.00	.98	.95	.55
7th				
Core-Year 2	91	91	79	59
(n = 91)	1.00	1.00	.87	.65
Retest	40	40	31	25
(n = 40)	1.00	1.00	.78	.63
10th				
Core-Year 2	86	86	79	73
(n = 86)	1.00	1.00	.92	.85
Retest	40	40	33	32
(n = 40)	1.00	1.00	.83	.80
All Grades				
Core-Year 2	343	345	2[illegible]	170
(N = 351)	.98	.98	.82	.48
Retest	154	154	127	79
(N = 160)	.96	.96	.79	.49

The number and proportion of core group children-year 1, and children who were the same chronological age but born one year later (cohort control) attaining each of the concept levels are presented in Table 13. For example, a comparison of the 82 kindergarten children in the core group and the 40 kindergarten children in the cohort control group reveals that the percentages of children attaining the four concept levels were very similar. Chi-square tests, performed at the .05 level of statistical significance, confirmed that cohort had no strong or systematic influence on proportions of children attaining the four concept levels either within grade or for all grades combined. Only a single Chi-square reached statistical significance. Among the ninth graders, a larger proportion of core group than cohort control group children attained the classificatory level (Chi-square = 14.61, d.f. = 1).

In summary, the predicted absence of repeated testing and cohort effects on attainment of the four concept levels has been supported.

Longitudinal Attainment of Equilateral Triangle and Conformity to the Model

Children in each grade block of the longitudinal sample can be evaluated on two performance dimensions simultaneously: (1) conforming or not conforming to the five acceptable patterns of concept attainment each year of assessment and (2) level of concept attainment year 2 relative to level of attainment at initial assessment: higher, same or lower. As observed in an earlier section, 86 percent of the children consistently conformed to acceptable patterns over both years of testing. But it is possible for a child to follow acceptable patterns at each assessment and yet fully attain at a lower concept level year 2 in comparison

TABLE 13

NUMBER AND PROPORTION OF CHILDREN IN EACH GRADE GROUP THAT FULLY MASTERED EACH LEVEL OF CONCEPT ATTAINMENT: COMPARING CORE GROUP-YEAR 1 AND COHORT CONTROL

Grade Group	Concrete	Identity	Classif.	Formal
Kg.				
Core-Year 1	66	66	32	0
(n = 82)	.80	.80	.39	.00
Cohort	30	31	20	0
(n = 40)	.75	.78	.50	.00
3rd				
Core-Year 1	89	87	71	15
(n = 92)	.97	.95	.77	.16
Cohort	38	37	29	6
(n = 40)	.95	.93	.73	.15
6th				
Core-Year 1	91	91	83	44
(n = 91)	1.00	1.00	.91	.48
Cohort	40	40	37	22
(n = 40)	1.00	1.00	.93	.55
9th				
Core-Year 1	86	86	85	69
(n = 86)	1.00	1.00	.99	.80
Cohort	40	40	32	27
(n = 40)	1.00	1.00	.80	.68
All Grades				
Core-Year 1	332	330	271	128
(N = 351)	.95	.94	.77	.36
Cohort	148	148	118	55
(N = 160)	.93	.93	.74	.34

with year 1. For example, a child exhibiting the PPPF pattern year 1 and the PPFF year 2 would obviously have attained to the classificatory level initially, but only to identity the following year. It is also possible for a child to follow unacceptable patterns both years (or any single year) and yet attain at a higher level year 2 compared to year 1. For example, a child exhibiting the FPFF pattern year 1 and the FPPF pattern year 2 would have fully mastered at a higher level at the time of the second assessment.

Table 14 presents the number and proportion of children in each grade block who fall into one of the 12 possible categories that combine conformity to acceptable patterns and level of attainment year 2 in comparison with that of year 1. Column one indicates conforming or not conforming to one of the five acceptable patterns of attainment year 1, column two indicates conforming or not conforming year 2, and column three indicates whether level of mastery year 2 was higher, the same, or lower than level of mastery year 1. Bear in mind that these data do not yet focus on the specific levels of concept attainment: concrete, identity, classificatory, and formal. At this point, we are only concerned with year 2 level of mastery relative to that of year 1.

The first row entries in Table 14 show that across all grades 95 children conformed both years and at a higher level of mastery the second year. Entries in the fifth row of the table show that across all grades 173 children conformed both years and at the same level of mastery year 2 as that attained year 1. Therefore, 268 children (nearly 80 percent of the longitudinal sample) consistently conformed to the model and attained at the same or at higher levels compared to year 1.

TABLE 14

NUMBER AND PROPORTION OF CHILDREN IN FOUR GRADE BLOCKS WHO CONFORMED OR NOT YEAR 1, CONFORMED OR NOT YEAR 2 AND LEVEL OF CONCEPT ATTAINMENT YEAR 2 COMPARED TO YEAR 1

Sequence					Grade Group Block				
Conformity to Model Year 1		Year 2		Year 2 level Attainment Compared to Yr. 1	Block 1 (n = 82)	Block 2 (n = 92)	Block 3 (n = 91)	Block 4 (n = 86)	All Grades
C	-	C	-	Higher:	35 .43	28 .30	22 .24	10 .12	95 .27
NC	-	C	-	Higher:	6 .07	0 .00	0 .00	0 .00	6 .02
C	-	NC	-	Higher:	2 .02	3 .03	3 .03	0 .00	8 .02
NC	-	NC	-	Higher:	0 .00	1 .01	0 .00	0 .00	1 .00
C	-	C	-	Same:	21 .26	39 .42	49 .54	64 .74	173 .49
NC	-	C	-	Same:	5 .06	6 .06	3 .03	0 .00	14 .04
C	-	NC	-	Same:	1 .01	3 .03	4 .04	3 .03	11 .03

Continued on next page.

TABLE 14, continued.

Conformity to Model Year 1	Sequence Year 2	Year 2 level Attainment Compared to Yr. 1	Grade Group Block Block 1 (n = 82)	Block 2 (n = 92)	Block 3 (n = 91)	Block 4 (n = 86)	All Grades
NC -	NC -	Same:	0 .00	0 .00	0 .00	0 .00	0 .00
C -	C -	Lower:	7 .09	10 .11	9 .10	8 .09	34 .10
NC -	C -	Lower:	5 .06	2 .02	1 .01	1 .01	9 .03
C -	NC -	Lower:	0 .00	0 .00	0 .00	0 .00	0 .00
NC -	NC -	Lower:	0 .00	0 .00	0 .00	0 .00	0 .00

Key: C = Conforming to model = following one of the 5 acceptable patterns of attainment
NC = Nonconforming to model = following one of the 11 non-acceptable patterns of attainment

Combining the first two rows of Table 14 indicates that 101 children (29 percent) attained at a higher level of concept mastery compared to the previous year and in an acceptable pattern by or before year 2. Similarly, by combining rows five and six, 187 children (53 percent) were observed to attain at the same level of mastery as the previous year and in an acceptable pattern by or before year 2. Altogether, 288 children (82 percent) attained at the same level or increased in level of attainment the second year of assessment and in one of the five acceptable patterns by year 2

Categories represented by rows three and four show that nine children (three percent) did not conform to the model either in both years or in year 2 but attained to a higher level of mastery year 2 compared to year 1. Categories represented by rows seven and eight show that 11 children (three percent) did not conform to the model year 2 but attained at the same level of mastery as the previous year. Thus a total of 20 children (six percent of the longitudinal sample) did not conform to the model the second year, or both years, but demonstrated concept mastery at the same level as the previous year or at a higher level. (In an earlier section item performances were examined for the 20 children who did not conform year 2 to one of the five acceptable patterns of concept mastery.)

Forty-three children (12 percent of the sample) followed an acceptable pattern year 2, or both years, but at a lower level of mastery than the previous year (see rows nine and ten). Note that no children showed both nonconformity to the model year 2 and a lower level of concept mastery than attained year 1. The item performances of the 43 children who followed acceptable patterns by or before year 2, yet who fully attained at a lower

level than the previous year, will be examined in detail in a later section of the present chapter.

Data in Table 14 also yield information about progress, stability, or loss in highest level of concept attainment over the first two years of longitudinal assessment. By collapsing the first four categories in this table we can determine the percentage of children who attained at a higher level year 2 in comparison with the initial mastery level, regardless of whether or not attainment was in accord with acceptable patterns. Collapsing the middle four categories and the last four categories separately reveals the percentage of children who remained stable in mastery level from year 1 to year 2 and the percentage of children losing one or more levels from year 1 to year 2.

The data in Table 15 have been derived in this manner and provide a clear summary of the percentages of children within each block and across all blocks showing progress, stability and loss in highest level of mastery from year 1 to year 2. Of the entire longitudinal sample, 31 percent (110 children) attained a higher level the second year of assessment than that attained initially. Fifty-six percent of the sample (198 children) exhibited a level of concept mastery year 2 identical to that of year 1. Forty-three children, or 12 percent of the sample, fully attained at a lower concept level year 2 in comparison with year 1.

Of the entire longitudinal sample, 308 children, or 88 percent, attained at the same level as the previous year or at higher levels.

It is also instructive to examine the relative contributions of the four grade blocks to the total percentages of children showing gains,

TABLE 15

NUMBER AND PROPORTION OF CHILDREN IN FOUR GRADE BLOCKS SHOWING GAIN, STABILITY OR LOSS IN CONCEPT ATTAINMENT FROM YEAR 1 TO YEAR 2

	Block 1 (n = 82)	Block 2 (n = 92)	Block 3 (n = 91)	Block 4 (n = 86)	All Grades (N = 351)
Gain of 1 or more levels yr. 2	43 .52	32 .35	25 .27	10 .12	110 .31
Stable - level of attainment same yr. 1 & yr. 2	27 .33	48 .52	56 .62	67 .78	198 .56
Loss of 1 or more levels yr. 2	12 .15	12 .13	10 .11	9 .10	43 .12

stability or loss in level of mastery. In general, Table 15 shows that Blocks 1 and 2 (the youngest children) contained the largest percentages of children progressing in level of concept mastery from first to second assessments, whereas Blocks 3 and 4 (the older children) contained the greatest numbers of children remaining stable from first to second assessments in highest level of mastery. In contrast, children whose highest level of attainment was lower year 2 than year 1 were about equally distributed across all four grade blocks. In the next sections these findings will be explored in detail.

Highest Level of Concept Attainment Year 2 in Comparison with Year 1

To review briefly, 31 percent of the longitudinal sample gained in mastery level, 56 percent remained stable, and 12 percent lost one or more levels from first to second assessments. Moreover, the four grade blocks tended to contribute differentially to these percentages. Although this information is useful, more critical information about the course of conceptual development is disclosed by examining the exact mastery performances from year 1 to year 2. The present section focuses on the particular sequence of highest mastery levels followed by children from year 1 to year 2 and provides more specific evidence for the fourth prediction.

The data presented in Table 16 permit precise examination of children's longitudinal performances in highest level of concept mastery from year 1 to year 2. These results now reveal why a preponderance of children in the higher grade blocks fell into the "stable" category and what exact sequences of mastery were responsible for children who "progressed." Data in Table 16 also are suggestive of the typical or modal sequence of concept attainment from year 1 to year 2 for each of the grade blocks.

TABLE 16

NUMBER AND PROPORTION OF CHILDREN IN FOUR GRADE BLOCKS SHOWING HIGHEST LEVEL OF CONCEPT ATTAINMENT YEAR 1 AND YEAR 2

No. Levels Increased from Year 1 to Year 2	Highest Level of Attainment Year 1		Year 2	Block 1 (n = 82)	Block 2 (n = 92)	Block 3 (n = 91)	Block 4 (n = 86)	All Grades (N = 351)
0	Formal	→	Formal	0	10	36	63	109
				.00	.11	.40	.73	.31
+1	Classif.	→	Formal	4	16	22	10	52
				.05	.17	.24	.12	.15
+2	Identity	→	Formal	3	5	1	0	9
				.04	.05	.01	.00	.03
+3	Concrete	→	Formal	0	0	0	0	0
				.00	.00	.00	.00	.00
+4	No levels	→	Formal	1	0	0	0	1
				.01	.00	.00	.00	.00
0	Classif.	→	Classif.	17	35	19	4	75
				.21	.38	.21	.05	.21
+1	Identity	→	Classif.	28	9	2	0	39
				.34	.09	.02	.00	.11
+2	Concrete	→	Classif.	1	2	0	0	3
				.01	.02	.00	.00	.01
+3	No levels	→	Classif.	2	0	0	0	2
				.02	.00	.00	.00	.01

Continued on next page.

TABLE 16, continued.

No. Levels Increased from Year 1 to Year 2	Highest Level of Attainment Year 1		Year 2	Block 1 (n = 82)	Block 2 (n = 92)	Block 3 (n = 91)	Block 4 (n = 86)	All Grades (N = 351)
0	Identity	→	Identity	10 .12	3 .03	1 .01	0 .00	14 .04
+1	Concrete	→	Identity	4 .05	0 .00	0 .00	0 .00	4 .01
+2	No levels	→	Identity	0 .00	0 .00	0 .00	0 .00	0 .00
0	Concrete	→	Concrete	0 .00	0 .00	0 .00	0 .00	0 .00
+1	No levels	→	Concrete	0 .00	0 .00	0 .00	0 .00	0 .00
-	Loss of 1 or more levels yr. 2			12 .15	12 .13	10 .11	9 .10	43 .12

Table 16 presents the number and proportion of children in each grade block who followed various sequences of concept level attainment in terms of highest level of mastery year 1 and highest level of mastery year 2; consequently, the number of levels increased (or decreased) from first to second assessment can be determined, and appears in the first column of the table.

For the formal level attainers year 2, there existed five possible "routes" to attainment at the formal level in relation to mastery level year 1: formal to formal; classificatory to formal; identity to formal; concrete to formal; and, finally, no levels fully mastered year 1 to formal level mastery year 2. Four possible sequential attainment routes were possible for those children attaining classificatory as their highest level year 2: classificatory to classificatory; identity to classificatory; concrete to classificatory; no levels to classificatory. The attainment routes for identity and concrete level attainment year 2 are similarly made explicit in Table 16. At the bottom of the table the number and proportion of children in each grade block losing one or more levels are included.

a. Performance of all children combined across blocks. Children whose performance indicated stability, then, were those whose highest mastery level was at formal, at classificatory, at identity, or at concrete for both years of assessment. None of the 351 children passed no levels both years. Children whose performance indicated gains were, of course, those who attained at a higher level year 2 in comparison with mastery level year 1. Inspection of Table 16 reveals that a large number of children were stable (198 children, or 56 percent, as reported earlier). Now it can be

determined that this result was largely due to those children who had attained to the highest level of concept mastery both years, reflecting a "ceiling effect" in concept attainment (109 children, or 31 percent of the total sample); 63 of the consistent formal level attainers were in Block 4 (or 73 percent of the oldest children). The next largest number of children showing stable attainment were at classificatory both years (75 children, or 21 percent). Fourteen children (four percent of the total sample) remained at identity both years and no children attained concrete as their highest level both years.

Performances of children stable in concept mastery may be further examined in terms of their following acceptable or nonacceptable patterns of attainment. Inspection of Table A-1 in Appendix A reveals that of the 109 children at formal both years the following pass/fail patterns of the four concept levels were observed from year 1 to year 2: PPPP to PPPP, 95 children; PFPP to PPPP, 1 child; PPFP to PPPP, 4 children; PPPP to PPFP, 8 children; and PPPP to FPPP, 1 child. Of the 75 children at classificatory both years the following patterns were observed from year 1 to year 2: PPPF to PPPF, 64 children; FPPF to PPPF, 2 children; PFPF to PPPF, 5 children; FFPF to PPPF, 2 children; PPPF to FPPF, 2 children. Of the 14 children at identity both years, all 14 followed the PPFF pattern both years. Thus, of the 198 children whose highest level of mastery year 2 was the same as that attained year 1, 173, or 87 percent, were in acceptable patterns both years (a finding already reported in Table 14). Now, however, it can be precisely determined that of these 173 children, 95 were stable at formal, 64 were stable at classificatory, and 14 were stable at identity.

Inspecting Table 16 for the distribution of children showing gains from year 1 to year 2 in highest level of attainment shows that the largest number of children making gains progressed from classificatory to formal--52 children, or 15 percent of the total sample. The next largest percentage is due to the children who progressed from identity to classificatory (39 children, or 11 percent of the total sample). Only four children (one percent) moved from concrete to identity. All of the children just described (95 children, or 27 percent) progressed in concept mastery from first to second assessments by gaining one higher concept level.

Performances of the children who progressed one level in concept mastery can also be examined in terms of their following acceptable or non-acceptable pass/fail patterns year 1 to year 2 (see Table A-1 in Appendix A). Of the 52 children who gained from classificatory to formal, 46 showed PPPF to PPPP patterns, 5 showed PPPF to PPFP patterns and 1 child showed FPPF to PPFP patterns. Of the 39 children progressing from identity to classificatory, 33 showed the PPFF to PPPF patterns year 1 to year 2 and 6 children showed FPFF to PPPF patterns. Finally, of the four children gaining from concrete to identity all followed the PFFF to PPFF patterns year 1 to year 2. Thus, of the 95 children who progressed one level in highest level of concept mastery, 87 percent (93 of the 95 children) were in acceptable patterns both years.

If the 198 children whose highest attainment levels both years were the same are combined with the 95 children whose highest attainment level year 2 was one level higher than that of year 1, we find that 293 children, or 83 percent of the longitudinal sample, attained at the same level as the previous year or at the next higher level (one concept level higher than that attained year 1).

Disregarding for the present those children who lost one or more levels from year 1 to year 2, it can be observed that the remainder of the longitudinal sample progressed in mastery by gaining two or more levels from year 1 to year 2. In order of frequency, examination of Table 16 reveals that nine children (three percent) gained from identity to formal (two levels gained); three children (one percent) gained from concrete to classificatory (two levels gained); two children (one percent) gained from no levels mastered year 1 to the classificatory level year 2 (three levels gained); and a single child gained from no levels year 1 to formal level attainment the second year of assessment (four levels gained). Altogether then, a total of 15 children (four percent of the longitudinal sample) progressed in level of mastery by gaining more than a single concept level.

Performances of the 15 children who gained two or more levels may be examined further in terms of their following acceptable or nonacceptable pass-fail patterns from year 1 to year 2 (see Table A-1 in Appendix A). Of the nine children gaining from identity to formal, six displayed the PPFF to PPPP patterns; two the PPFF to PPFP patterns, and one child the PPFF to PFFP patterns. The single child progressing from no levels to formal showed FFFF to PPPP patterns year 1 to year 2. The three children gaining from concrete to classificatory all were observed in PFFF to PPPF pass/fail patterns. Finally, the two children attaining no levels year 1 but classificatory year 2 were both in the FFFF to PPPF sequence. Thus, of the 15 children who gained two or more levels from year 1 to year 2, 12 children or 80 percent followed acceptable patterns both years of assessment.

Although the majority of the children who progressed in level of attainment from year 1 to year 2 did so by gaining one concept level, gaining

two or more levels may have been due to a variety of factors. For these children, the testing interval of one year may have been too great to register separately the successive gains in attainment level. Or, a child may have just barely missed meeting the pass/fail criterion for attainment at a particular level at the time of initial assessment (due to errors of measurement; criterion stringency). Performance the following year might then reflect attainment of that particular level as well as the next higher level. Or, the child might for some reason have received explicit instruction in the period intervening between first and second assessments sufficient to accelerate the child's mastery two or more levels beyond that exhibited at initial testing. Only one of the 351 children in the longitudinal sample (a child in Block 1 as Table 16 shows) displayed the dramatic jump from no levels fully mastered year 1 to mastery of all levels, including formal, year 2.

In summary, more than half of the 198 children who showed no progress in highest level of mastery from year 1 to year 2 were at formal both years (a ceiling in performance); 95 children gained one concept level from year 1 to year 2, and 15 children gained two or more levels from first to second assessments. These more specific findings are viewed as further strong support for the fourth prediction stating that a child will master a concept at the same level as the previous year, or at higher levels.

b. Performances of each grade block. Table 16 also permits examination of performances of the individual blocks of the longitudinal sample. Children who were kindergarteners year 1 and first graders year 2 (Block 1) were distributed over 9 of the 14 possible highest level of attainment sequences shown in Table 16 (disregarding for the present children who lost one or more levels). Children who were third graders year 1 and fourth

graders year 2 (Block 2) were distributed over 7 of the 14 possible sequences; children in Block 3, sixth graders who became seventh graders year 2, were distributed over 6 of the 14 sequences and children who were ninth graders year 1 and tenth graders year 2 (Block 4) appear in only 3 of the sequences. Thus, with increasing grade fewer of the possible attainment sequences were followed--performance became decreasingly variable.

We can now also discern the modal sequence of concept attainment followed by each of the four blocks. Consider the highest attainment level sequences observed from first to second assessments in Block 1. The largest percentage of the youngest childred gained from identity year 1 to classificatory year 2 (34 percent). More than half of the 82 Block 1 children either were at classificatory both years (21 percent) or progressed from identity to classificatory. The next single largest percentage of children remained at identity both years of assessment (12 percent). The remaining Block 1 children were distributed fairly evenly over six of the remaining attainment sequences.

The largest single percentage of children in Block 2 were at classificatory both years of assessment (38 percent). In addition, a third of the 92 children in this block had attained to the formal level both years or demonstrated formal level mastery by year 2.

The modal attainment sequence observed in Block 3 children was stable attainment at the formal level both years (40 percent of the 91 children). The next largest percentage of children gained to formal year 2 from classificatory year 1 (24 percent). Twenty-one percent of the children in Block 3 were also stable at classificatory both years.

Among the 86 children in Block 4, 73 percent were at formal both years of assessment. Twelve percent gained to formal year 2 from classificatory

year 1. Only five percent of the oldest children remained at classificatory both years.

c. Pass/fail stability in attainment of levels and item performance. Table 17 presents a summary of the number and proportion of children in each grade block whose highest level of attainment year 2 was unchanged from that observed year 1 (a total of 198 children). No children in the longitudinal sample attained concrete as their highest level both year 1 and year 2; therefore, only data for subjects who were at identity, classificatory, or formal both years of longitudinal assessment are shown. The data were, of course, based on the pass/fail criteria for attainment of each level. It is instructive to examine the item protocols of the 198 children whose attainment level was unchanged from year 1 to year 2 for any increases in the actual number of items passed on the next higher levels. The dichotomous pass/fail data might have masked fairly substantial item gains made by these children on subtests at higher levels.

Across blocks, 14 children showed highest level of attainment at identity both years in terms of pass/fail data (10 in Block 1; 3 in Block 2; 1 in Block 3). An examination of the item performances on higher subtests revealed that only four of these children made gains in number of classificatory items passed (two of these children were in Block 1; two in Block 2); seven children passed exactly the same number of classificatory items year 1 and year 2 (five in Block 1; one in Block 2; one in Block 3); three children (all in Block 1) passed fewer classificatory items year 2 in comparison with year 1. Thus, the pass/fail dichotomy reflected fairly accurately stability in identity level performance. Eleven of the 14 children (eight in Block 1; two in Block 2; one in Block 3) increased in number of

TABLE 17

NUMBER AND PROPORTION OF CHILDREN IN EACH GRADE BLOCK SHOWING PASS/FAIL STABILITY IN HIGHEST LEVEL OF CONCEPT MASTERY FROM YEAR 1 TO YEAR 2

Grade Group Block	At Identity Year 1 & Year 2	At Classif. Year 1 & Year 2	At Formal Year 1 & Year 2
Block 1	10	17	0
(n = 82)	.12	.21	.00
Block 2	3	35	10
(n = 92)	.03	.38	.11
Block 3	1	19	36
(n = 91)	.01	.21	.40
Block 4	0	4	63
(n = 86)	.00	.05	.73
All Grades	14	75	109
(N = 351)	.04	.21	.31

formal items passed year 2, however; two children (one in Block 1; one in Block 2) passed fewer formal items year 2 than year 1.

Across blocks, 75 children were at classificatory both years of longitudinal assessment in terms of pass/fail data. Analysis of formal subtest item protocols showed that 43 of these children (11 in Block 1; 19 in Block 2; 11 in Block 3; 2 in Block 4) made gains in number of items passed on the formal subtest. Fifteen children (three in Block 1; seven in Block 2; four in Block 3; one in Block 4) passed the same number of formal items year 2 as year 1; 17 children (three in Block 1; nine in Block 2; four in Block 3; one in Block 4) passed fewer formal items year 2 than year 1.

The largest percentage of children whose highest attainment level remained unchanged from year 1 to year 2 fully mastered the formal level both years; examination of the item performances of these 109 children is, of course, not relevant to the major concern of this section. The exact item performances at higher levels for children showing pass/fail stability in highest level of concept mastery from year 1 to year 2 are provided in Table A-3 in Appendix A and are available for further scrutiny.

d. Pass/fail loss in highest level of attainment and item performance. Table 18 presents the number and proportion of children in each grade block fully attaining at a lower mastery level year 2 in comparison with year 1 in terms of pass/fail criteria. This table is organized to show highest level of attainment year 1 in relation to the lower mastery level year 2. An examination of the item performances of these 43 children may help to determine why attainment level year 2 fell. (Table A-4 in Appendix A presents, for each child losing one or more levels, a complete description of item performances on level(s) attained year 1 but not year 2.)

TABLE 18

NUMBER AND PROPORTION OF CHILDREN EACH IN GRADE BLOCK SHOWING PASS/FAIL LOSS IN HIGHEST LEVEL OF CONCEPT MASTERY FROM YEAR 1 TO YEAR 2

Grade Group Block	Classif. Yr. 1 but Identity Yr. 2	Formal Yr. 1 but Classif. Yr. 2	Loss of 2 or more Concept Levels Yr. 2
Block 1 (n = 82)	7 .09	0 .00	5 .06
Block 2 (n = 92)	7 .08	5 .05	0 .00
Block 3 (n = 91)	2 .02	6 .07	2 .02
Block 4 (n = 86)	2 .02	5 .06	2 .02
All Grades (N = 351)	18 .05	16 .05	9 .03

Eighteen children, mainly from Blocks 1 and 2, attained to the classificatory level year 1 but only to identity year 2. Fourteen of these children lost just a single classificatory item year 2. It will be recalled from Table 5 that the classificatory subtest contains three items and all are required to meet criterion for classificatory level mastery. Thus, a loss of just one item will determine the difference between passing or failing. Four children lost more than one classificatory item. Thus, it seems reasonable to conclude that criterion stringency, as well as some degree of carelessness, were responsible for loss of the classificatory level at the second assessment.

Sixteen children, all from Blocks 2, 3, and 4 attained formal year 1 but only to classificatory year 2. It will be recalled from Table 5 that the formal subtest contains ten items--seven vocabulary items and three discriminating attribute items. Criterion for mastery required passing five vocabulary and two discriminating attribute items. Five of these 16 children lost just one vocabulary item year 2; seven lost two vocabulary items and four children lost more than two vocabulary items. Eleven of these children, although losing vocabulary items, remained stable in performance on discriminating attributes items. Three children lost vocabulary items but gained discriminating attributes items; two lost items on discriminating attributes as well as on vocabulary. Thus, it appears that for children who attained to formal year 1 but only to classificatory year 2, a loss of vocabulary items was primarily responsible for failure to meet the criterion for formal level mastery year 2.

Across grade blocks nine children, mainly from Block 1, lost two or more concept levels year 2 in comparison with year 1. Of the five children in Block 1, four attained at identity or classificatory levels year 1 but

fully mastered no levels year 2. Examination of item performances indicated erratic patterns of item losses at the year 2 assessment (including a few gains in vocabulary items). The fifth child attained to the classificatory level year 1 (but not concrete or identity) and year 2 attained only to concrete. Item performance of this child showed gains on the first two subtests, losses on classificatory and formal items.

In Block 3 two children attained to formal year 1 and dropped to identity as highest level mastered year 2. For both children a loss of four vocabulary items was responsible for non-mastery at the formal level year 2, but performance on discriminating attributes items was unchanged. One child also lost a single classificatory subtest item; the second child had attained classificatory neither year (although formal was attained year 1).

In Block 4 two children dropped from formal level mastery year 1 to identity level mastery year 2. Both of these children lost discriminating attributes items; one gained in vocabulary items and one lost vocabulary items.

Among the nine children (three percent of the longitudinal sample) who lost two or more concept levels from year 1 to year 2, examination of item performances thus reveals no systematic pattern in terms of type or number of items lost. Perhaps, at least for the present, the most reasonable explanation for these most extreme cases of loss in level of concept mastery is carelessness and inattentiveness on the part of these children during the second assessment. In this regard, it is notable that the most severe losses were incurred by the youngest children; loss of more than two concept levels was observed exclusively in Block 1.

Charting Mastery of Items on the Four Concept Levels from Year 1 to Year 2 for Four Grade Blocks

The present section addresses the question of how acquisition of the equilateral triangle concept changes over a two year time span; this conceptual development will be represented in terms of item performance, a more sensitive index than pass/fail data, on each of the four concept levels. The shape of the developmental curve at each level is preliminary at this point in the longitudinal study, since data are presently available only for the first two years of data collection.

Table 19 presents the means and standard deviations of items correct on each concept level subtest, and separately for the two components of the formal subtest. The columns show mean items correct on each subtest for each grade group block for each year of longitudinal assessment.

Inspection of the columns reveals an overall trend, with few exceptions, for mean number of items answered correctly to increase with each year of assessment within each block, as well as across blocks. (Consequently, these means reflect both longitudinal and cross-sectional data.) For example, on the formal subtest which is composed of ten items, Block 1 children obtained a mean of 2.18 items correct year 1, 4.24 mean items correct year 2. Block 2 children obtained a mean of 5.20 correct items at initial assessment, 6.35 mean items correct at the second assessment. In Block 3, means were 7.01 and 7.95 and in Block 4, 8.49 and 8.74.

Converting these means to percentages permits comparability of performance on the four concept levels; mean percentages of items correct are presented in Table 20. From these mean percentage data, Figure 3 constructs the developmental curves for each of the four concept levels and separately for the two components of formal (vocabulary and discriminating

TABLE 19

MEANS AND STANDARD DEVIATIONS OF ITEMS CORRECT ON EACH CONCEPT LEVEL SUBTEST (AND SEPARATELY FOR THE TWO COMPONENTS OF FORMAL) FOR FOUR GRADE BLOCKS

		Concept Levels											
Total Items =		Concrete 8		Identity 8		Classif. 3		Formal 10		Vocab. 7		Dis. Attr. 3	
		M	S.D.	M	S.D.	M	S.D.	M	S.D.	M	S.D.	M	S.D.
Block 1 (n = 82)	Year 1	7.27	1.23	7.09	1.22	2.10	0.88	2.18	1.27	1.16	0.84	1.02	1.01
	Year 2	7.74	0.61	7.76	0.56	2.47	0.87	4.24	1.88	2.52	1.46	1.70	1.10
Block 2 (n = 92)	Year 1	7.74	0.77	7.75	0.64	2.62	0.82	5.20	2.09	2.94	1.72	2.26	1.03
	Year 2	7.84	0.52	7.84	0.40	2.74	0.68	6.35	2.01	3.71	1.61	2.64	0.75
Block 3 (n = 91)	Year 1	8.00	0.00	8.00	0.00	2.88	0.44	7.01	2.13	4.55	1.60	2.46	0.97
	Year 2	8.00	0.00	8.00	0.00	2.82	0.53	7.95	1.89	5.18	1.60	2.77	0.63
Block 4 (n = 86)	Year 1	8.00	0.00	8.00	0.00	2.99	0.10	8.49	1.55	5.80	1.25	2.69	0.71
	Year 2	8.00	0.00	8.00	0.00	2.84	0.59	8.74	1.76	5.91	1.44	2.84	0.57

TABLE 20

MEAN PERCENTAGE OF ITEMS CORRECT ON FOUR CONCEPT LEVELS AND SEPARATELY FOR TWO COMPONENTS OF FORMAL FOR EACH GRADE BLOCK

Blocks	Grade	Concrete 8	Identity 8	Classif 3	Formal 10	Vocab 7	Dis Attr 3
Block 1 (N = 82)	K	90.8	88.6	70.0	21.8	16.5	34.0
	1	96.7	97.0	82.3	42.4	36.0	56.6
Block 2 (N = 92)	3	96.7	96.8	87.3	52.0	42.0	75.3
	4	98.0	98.0	91.3	63.5	53.0	88.0
Block 3 (N = 91)	6	100.0	100.0	96.0	70.1	65.0	82.0
	7	100.0	100.0	94.0	79.5	74.0	92.3
Block 4 (N = 86)	9	100.0	100.0	99.6	84.9	82.8	89.6
	10	100.0	100.0	94.6	87.4	84.4	94.6

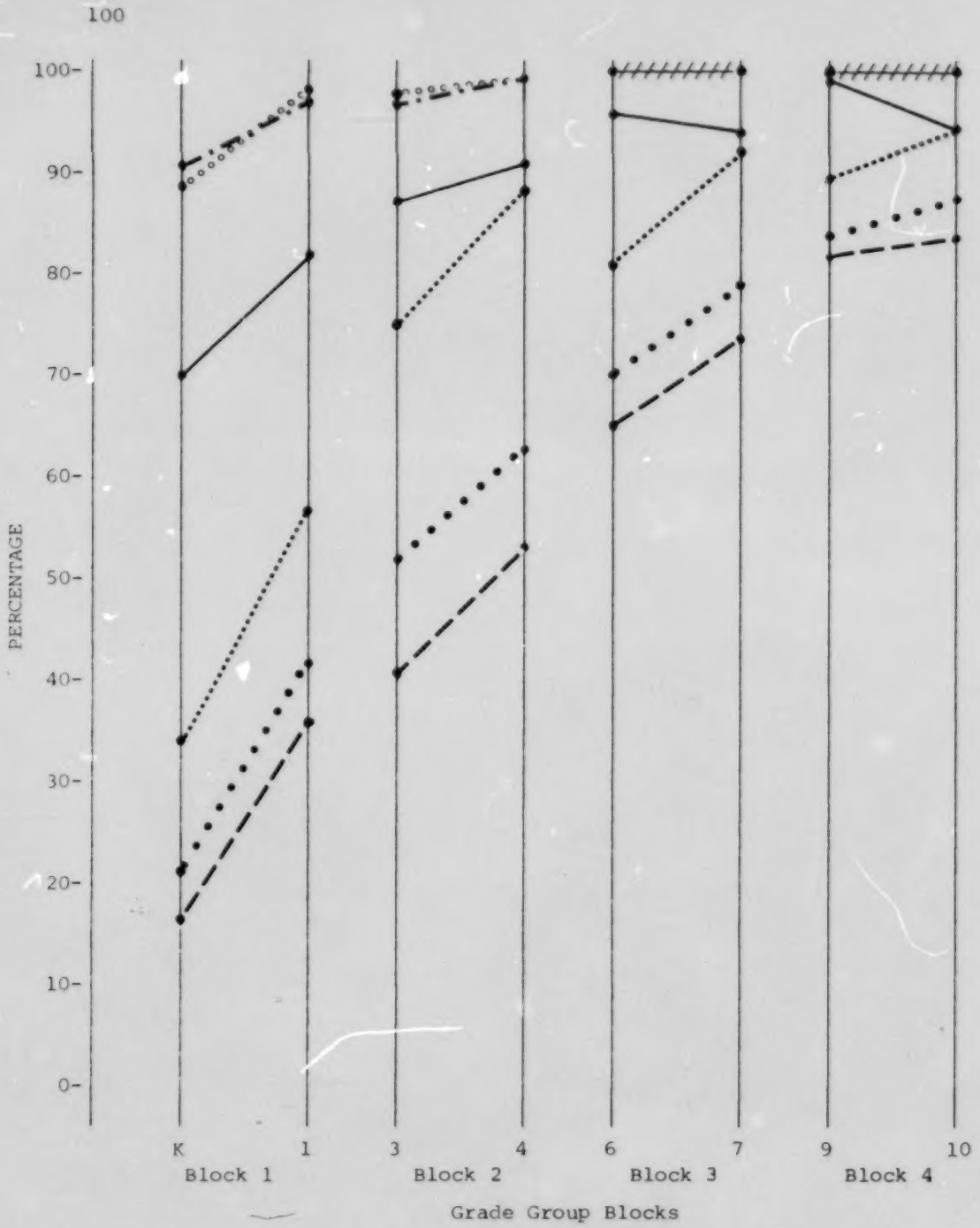

Figure 3. Mean percentage items correct on four concept levels for four grade blocks: year 1 and year 2 of longitudinal assessment.

°°°°°°°°°°°	Identity	·····	Discriminating Attributes
··—·—·—	Concrete	• • • • • •	Formal
//////////	(Concrete and Identity)	— — — — —	Vocabulary
————	Classificatory		

attributes) over the first two years of longitudinal assessment. Thus, these curves are restricted and preliminary in terms of reflecting developmental change. They are essentially a first estimation of conceptual development in the acquisition of equilateral triangle.

Figure 3 indicates a high level of attainment at concrete and identity levels even for the youngest children. By fourth grade, the curves flatten and remain so through tenth grade indicating a ceiling in attainment. The curve describing classificatory attainment starts at a point considerably below those for concrete and identity, and accelerates gradually and smoothly. The curve for formal level attainment is clearly the steepest of the four, indicating a large performance increment from Block 1 to Block 4. Vocabulary attainment closely parallels the curve for formal, of which it is a component; the curve showing performance of the four grade blocks on discriminating attributes, although somewhat erratic, is in all cases higher than the curve representing total formal level performance. For the equilateral triangle concept, these curves suggest that vocabulary is initially the more difficult component of the formal subtest and is acquired more slowly than the discriminating attributes component. (Please recall that the present data are based on an incomplete version of the formal level subtest.)

Although data are based on a minimum of longitudinal information (two measurements) these curves still provide an initial graphic representation of developmental trends. As measurement in the longitudinal program continues, future curves charting development of the concept levels

will more accurately describe age changes in the acquisition of the equilateral triangle concept, as well as in other concepts.

Separately for each grade block, Figure 4 shows the curves for the mean percentage of items correct on the four concept levels at each year of longitudinal assessment. These curves, constructed from the row percentage data presented in Table 20, indicate that the greatest improvement in item performance on concept levels subtests from 1973 to 1974 occurred in Block 1. As grade blocks increase, item performance increments on the levels become smaller in magnitude from first to second assessments, largely because the older children in the longitudinal sample exhibited a ceiling in attainment on concrete and identity, and approach a ceiling on classificatory. In both Blocks 3 and 4 performance on the classificatory subtest items was slightly superior in 1973 compared to 1974.

RELATION BETWEEN FULL ATTAINMENT OF THE VARIOUS LEVELS BY YEAR 2 AND FULL MASTERY OF THE USES

The fifth prediction derived from the CLD model specifies that individuals who have attained a concept only to the concrete or to the identity level by the second year of longitudinal assessment may be able to use that concept in cognizing simple perceptual relations among concepts and in solving simple problems of a perceptual kind but that they will not be able to use the concept in understanding supraordinate-subordinate relations, understanding principles, or in solving more complex problems. An evaluation of this prediction is possible from data shown in Table 21.

Table 21 presents, for each group of children whose highest level of concept attainment year 1 and year 2 was as indicated at the left of the table, the number and proportion of children within each block passing each

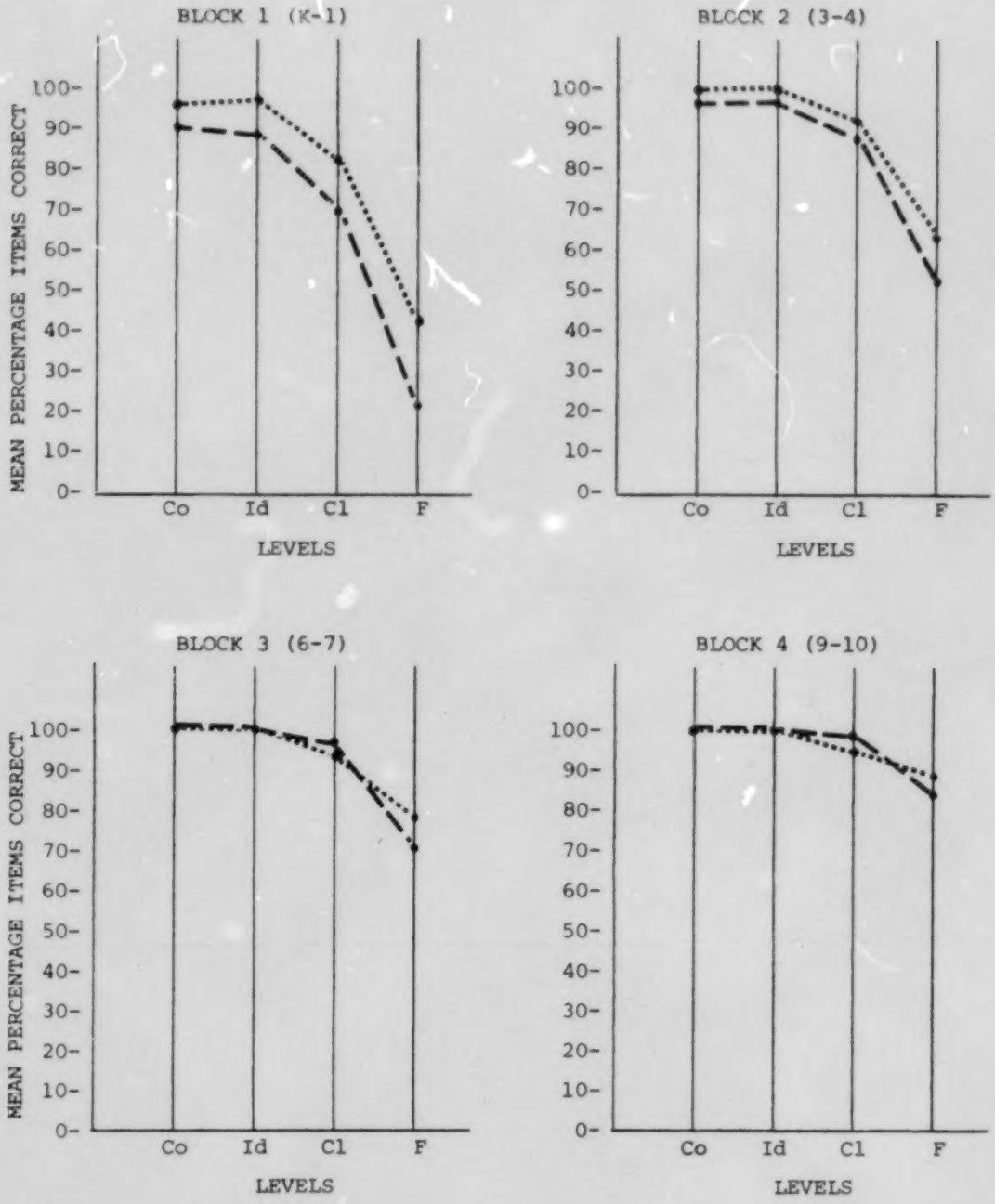

Figure 4. Mean percentage of items correct on four concept levels for each grade block: year 1 and year 2 of longitudinal assessment.

– – – – – 1973
..... 1974

TABLE 21

RELATIONSHIP BETWEEN HIGHEST LEVEL OF CONCEPT ATTAINMENT
FROM YEAR 1 TO YEAR 2 AND MASTERY OF THE USES YEAR 2

	Block 1			Block 2			Block 3			Block 4			All Grades		
Highest Level	Prin	Prob Solv	Supra Sub	Prin	Prob Solv	Supra Sub	Prin	Prob Solv	Supra Sub	Prin	Prob Solv	Supra Sub	Prin	Prob Solv	Supra Sub
At Formal Yr. 1 and Yr. 2															
N at level	0			10			36			63			109		
N Pass Use	0	0	0	1	0	1	13	20	9	44	52	39	58	72	49
Proportion	.00	.00	.00	.10	.00	.10	.36	.55	.25	.70	.83	.62	.53	.66	.45
Gain to Formal Yr. 2															
N at Level	8			21			23			10			62		
N Pass Use	0	0	0	0	7	7	6	8	2	4	4	3	10	19	12
Proportion	.00	.00	.00	.00	.33	.33	.26	.35	.09	.40	.40	.30	.16	.31	.19
Gain to Formal Yr. 2 from Classif. Yr. 1															
N at Level	4			16			22			10			52		
N Pass Use	0	0	0	0	6	6	6	7	2	3	4	4	9	17	12
Proportion	.00	.00	.00	.00	.38	.38	.27	.32	.09	.30	.40	.40	.17	.33	.23

Continued on next page.

TABLE 21, continued.

Highest Level	Block 1			Block 2			Block 3			Block 4			All Grades		
	Prin	Prob Solv	Supra Sub	Prin	Prob Solv	Supra Sub	Prin	Prob Solv	Supra Sub	Prin	Prob Solv	Supra Sub	Prin	Prob Solv	Supra Sub
At Classif. Yr. 1 and Yr. 2															
N at Level	17			35			19			4			75		
N Pass Use	0	0	0	1	3	4	1	3	1	1	1	1	3	7	6
Proportion	.00	.00	.00	.03	.09	.11	.05	.16	.05	.25	.25	.25	.04	.09	.08
Gain to Classif. Yr. 2															
N at Level	31			11			2			0			44		
N Pass Use	0	0	0	0	2	1	0	0	0	0	0	0	0	2	1
Proportion	.00	.00	.00	.00	.18	.09	.00	.00	.00	.00	.00	.00	.00	.05	.02
At Identity Yr. 1 and Yr. 2															
N at Level	10			3			1			0			14		
N Pass Use	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Proportion	.00	.00	.00	.00	.00	.33	.00	.00	.00	.00	.00	.00	.00	.00	.08

Continued on next page.

TABLE 21, continued.

Highest Level	Block 1			Block 2			Block 3			Block 4			All Grades		
	Prin	Prob Solv	Supra Sub	Prin	Prob Solv	Supra Sub	Prin	Prob Solv	Supra Sub	Prin	Prob Solv	Supra Sub	Prin	Prob Solv	Supra Sub
Gain to Identity Yr. 2															
N at Level	4			0			0			0			4		
N Pass Use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Proportion	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Loss of 1 or more Levels Yr. 2															
N at Level	12			12			10			9			43		
N Pass Use	0	0	0	0	1	0	1	3	2	1	1	0	2	5	2
Proportion	.00	.00	.00	.00	.08	.00	.10	.30	.20	.11	.11	.00	.05	.12	.05

of the three concept uses. Data presented earlier revealed that no children attained concrete as their highest level year 2 or remained at that level of mastery from year 1 to year 2. However, four children (from Block 1 as Table 21 shows) gained to identity as their highest level of mastery year 2; none of these children demonstrated mastery of any of the uses. Fourteen children were at identity both years of assessment and of these a single child from Block 2 met criterion for mastery on one uses subtest (supraordinate-subordinate). It seems very clear, then, that the fifth prediction was borne out by these data.

The sixth longitudinal prediction deals with the expectation of superior performance on the uses subtests by children attaining at the formal level by year 2 compared with those attaining at the classificatory level by year 2. Table 21 presents the number and proportion of children mastering each of the uses as a function of: (1) their attainment of the formal level both years; (2) gain to formal by year 2; (3) attainment of classificatory both years; and (4) gain to classificatory by year 2. Combining the two groups of formal level attainers across all blocks results in 171 children attaining to the formal level by or before year 2 and combining the two groups of classificatory level attainers results in 119 children attaining to this level by or before year 2. Among the 171 formal level attainers, we find that 68 children mastered the principles subtest, 91 the problem solving subtest and 61 the supraordinate-subordinate subtest. In contrast, among the 119 classificatory level attainers, 3 passed principles, 9, problem solving, and 7, supraordinate-subordinate. Chi-square tests confirmed a statistically significant advantage (beyond the .001 level) for children attaining at the formal level when compared

to those attaining at the classificatory level [Chi-square = 53.53, principles; 64.73, problem solving; 32.32, supraordinate-subordinate (d.f. = 1)].

A more specific prediction regarding performance on the uses by formal level attainers in comparison with classificatory level attainers focuses only on the children whose highest level of attainment was at classificatory year 1 and who attained to formal year 2; the comparison group is represented by the children whose highest level of attainment was at classificatory both years 1 and 2. These two groups of children are also isolated in Table 21. Inspection shows that 75 children, across all blocks, attained classificatory as their highest level both years; 52 children gained from classificatory as their highest level year 1 to formal year 2. Of the 52 children progressing from classificatory to formal, 9 fully mastered the principles subtest; 17, problem solving; 12, supraordinate-subordinate. Of the 75 children remaining at classificatory both years, 3 mastered principles, 7 mastered problem solving, and 6, supraordinate-subordinate. Chi-square tests confirmed, with statistical significance ($p < .05$) superior performance on all three uses subtests by children gaining to formal year 2 from classificatory year 1 [Chi-square = 6.36, principles; 10.93, problem solving; 5.74, supraordinate-subordinate (d.f. = 1)].

The longitudinal results strongly support prediction six and attest to the fact that, when compared with attainment at the classificatory level, attainment of a concept at the formal level has a marked facilitative effect on ability to use the concept.

MASTERY OF THE THREE CONCEPT USES

The present section is concerned with age changes in mastery of the principles, problem solving, and supraordinate-subordinate subtests. Before considering the performance changes from year 1 to year 2 in the longitudinal core group children, evidence will be evaluated bearing on the seventh prediction: neither retesting in the longitudinal study nor being a member of a specific cohort was expected to significantly influence mastery of the three uses.

Influence of Retesting and Cohort on Mastery of the Uses

For each grade group, Table 22 shows the number and proportion of children in the longitudinal core group-year 2 and retest control group who mastered each of the three uses subtests. Comparisons indicate that performances of core and control groups were fairly similar. For example, across grade groups, 21 percent of the children tested twice in the longitudinal program mastered principles; 30 percent, problem solving; and 20 percent, supraordinate-subordinate. Of the entire retest control group, 18 percent mastered principles; 22 percent, problem solving; 29 percent, supraordinate-subordinate.

Chi-square tests were performed in order to determine if any statistically significant differences ($p < .05$) occurred in the proportions of core group and retest control group children mastering each of the uses within each grade and for all grades combined. Within grade analyses resulted in two differences that reached statistical significance, both in the fourth grade. A larger proportion of retest control children mastered principles when compared to the core group-year 2 (Chi-square = 5.92, d.f. = 1); but a larger proportion of the core group children mastered problem solving when

TABLE 22

NUMBER AND PROPORTION OF CHILDREN IN FOUR GRADE GROUPS SHOWING MASTERY OF THREE CONCEPT USES: COMPARING CORE GROUP-YEAR 2 AND RETEST CONTROL

Grade Group	Principle	Problem Solving	Supraordinate-Subordinate
1st			
Core-Year 2	0	0	0
(n = 82)	.00	.00	.00
Retest Control	1	0	0
(n = 40)	.03	.00	.00
4th			
Core-Year 2	2	13	14
(n = 92)	.02	.14	.15
Retest Control	5	1	11
(n = 40)	.13	.03	.28
7th			
Core-Year 2	21	34	14
(n = 91)	.23	.37	.15
Retest Control	4	10	10
(n = 40)	.10	.25	.25
10th			
Core-Year 2	50	58	43
(n = 86)	.58	.67	.50
Retest Control	18	24	26
(n = 40)	.45	.60	.65
All Grades			
Core-Year 2	73	105	71
(N = 351)	.21	.30	.20
Retest Control	28	35	47
(N = 160)	.18	.22	.29

compared to the controls (Chi-square = 3.98, d.f. = 1). Combining data across grades resulted in a significant difference on the supraordinate-subordinate subtest: more control group than core group children mastered this subtest (Chi-square = 5.18, d.f. = 1). Consequently, it appears reasonable to conclude that repeated participation in the longitudinal assessment had no marked or systematic biasing effects on performance on the uses subtests.

Data permitting a comparison of performances on the three concept uses by children in the core group-year 1 and those of the same chronological age but born one year later (cohort controls) are presented in Table 23. Comparisons between the two groups in terms of the number and proportion of children mastering each uses subtest at each grade and for all grades combined does reveal some disparities, especially at the sixth and ninth grades. Chi-square tests within grades and for all grades combined were performed in order to discover if these differences were statistically significant ($p < .05$). Among third graders, the cohort control children were superior in mastery of the supraordinate-subordinate subtest (Chi-square = 4.18, d.f. = 1). Among ninth graders, the core group was superior in mastery of the principles subtest (Chi-square = 17.23, d.f. = 1). But on problem solving and supraordinate-subordinate, the ninth-grade cohort control group was superior to the core group [Chi-square = 5.74, problem solving; 4.15, supraordinate-subordinate (d.f. = 1)]. Among the sixth graders, a larger proportion of the cohort control group consistently mastered each of the concept uses when compared to the core group [Chi-square = 5.63, principles; 25.96, problem solving; 30.80, supraordinate-subordinate (d.f. = 1)]. Across all grades, children in the cohort control group were also superior to core

TABLE 23

NUMBER AND PROPORTION OF CHILDREN IN FOUR GRADE GROUPS SHOWING MASTERY OF THREE CONCEPT USES: COMPARING CORE GROUP-YEAR 1 AND COHORT CONTROL

Grade Group	Principle	Problem Solving	Supraordinate-Subordinate
Kg.			
Core-Year 1	0	0	0
(n = 82)	.00	.00	.00
Cohort Control	0	0	0
(n = 40)	.00	.00	.00
3rd			
Core-Year 1	0	0	3
(n = 92)	.00	.00	.03
Cohort Control	1	0	5
(n = 40)	.03	.00	.13
6th			
Core-Year 1	10	1	8
(n = 91)	.11	.01	.09
Cohort Control	11	12	21
(n = 40)	.28	.30	.53
9th			
Core-Year 1	49	32	23
(n = 86)	.57	.37	.27
Cohort Control	7	24	18
(n = 40)	.18	.60	.45
All Grades			
Core-Year 1	59	33	34
(N = 351)	.17	.09	.10
Cohort Control	19	36	44
(N = 160)	.12	.23	.28

group children in performance on two of the three uses [Chi-square = 16.14, problem solving; 26.96, supraordinate-subordinate (d.f. = 1)].

It cannot be concluded, therefore, that cohort differences had no important influence in mastery of the uses. Statistically significant findings quite systematically demonstrated superior performance on uses for the cohort children at all grades except kindergarten, and especially in sixth and ninth. Careful consideration of any factors that might have been responsible for these results is certainly warranted. First it is noteworthy that, as described in earlier sections, the cohort and core group children did not differ in conformity to the predicted invariant sequence or in attainment of the four concept levels. In fact, performance on classificatory and formal subtests (of particular importance because of the predicted intimate relation between attainment of the highest concept levels and ability to master the uses) was quite comparable for these two groups of children.

It will be recalled that the 160 cohort control group children were randomly drawn from the same schools and classrooms as the longitudinal core children. Although superior performance on the uses subtests was not confined to a single grade group of the cohort controls, it was most pronounced at the sixth grade. An attempt was made to determine if the superior performance of the sixth-grade cohort children was associated with superior I.Q. or school achievement test scores. Scores on the Otis-Lennon Mental Abilities Test, administered to children as fifth graders, were examined for randomly drawn groups of 20 sixth grade core children and 20 sixth-grade cohort children. The difference in mean scores (core group $\bar{X}$ = 102.7; cohort group $\bar{X}$ = 99.6) for the two groups did not approach statistical significance (t = 0.65, d.f. = 38). It seemed reasonable, therefore, to rule out

an explanation based on markedly superior intellectual abilities (as measured by the Otis Test) of the cohort children. It was also ascertained from teachers that no curriculum changes had been introduced in the schools to which superior cohort performance on the uses of equilateral triangle could reasonably be attributed.

Since statistical evidence of superior performance on the uses subtests by the cohort children in comparison with the core group children was observed at every grade (except kindergarten), it would seem advisable to examine the specific test-taking conditions for any situational differences that might have systematically benefited the cohort children. One factor that might be salient for explaining these performance discrepancies is that the two groups of children were examined by different testers. We have no way of knowing, however, precisely how this difference in testers may have operated to influence differentially the two groups of children. Also of potential significance in explaining their superior performance on the uses subtest, is the fact that cohort control children were administered the assessment batteries in groups that were considerably smaller in size than those used with core group children. The core group-year 1 was tested primarily in intact classrooms of 25 or 30 or more children (with the exception of kindergarteners). The cohort control group children were tested generally in smaller groups--occasionally containing as few as six children. It is possible that performance on the more difficult of the CLD subtests was enhanced when testing occurred in small groups. Noise, distractibility, and inattention were much less likely in smaller groups and task-oriented behavior more easily sustained. It is also possible that some unique combination of tester and group size effects elicited the superior test performances observed in the cohort children.

One final possibility for explaining the differences in cohort and core group performance is that third, sixth, and ninth grade cohort children had received information about the tests from previously tested children. This possibility seems less likely than others, however, for if critical information concerning these tests was being transmitted in the schools on this widespread a basis, it is difficult to understand why retest control group children did not also benefit from it. Moreover, neither teachers nor the second year test administrators were cognizant of any widespread information exchange among the students regarding the testing program.

Because it is difficult to be more precise at the present time in isolating the source of the core-cohort differences in mastery of the uses subtests, the cohort control group children merit close scrutiney during their continued participation in the longitudinal program.

In summary, the seventh prediction received support insofar as performance on the uses by the retest control group did not differ from that of the children who were administered the uses subtests twice. The second half of prediction seven was not supported. The cohort control group children from grades three, six, and nine exhibited superior mastery of the uses when compared to children in the core group-year 1. Tentative explanations were offered in terms of test-taking situational differences.

Gain, Stability, and Loss in Mastery of the Three Uses

Table 24 is organized to show the number and proportion of children in each grade group block who gained, remained unchanged, or lost from year 1 to year 2 in meeting criteria for full mastery of each concept use. Gain in mastery was demonstrated if the child failed to meet mastery criteria year 1 but did so year 2. Stable performance resulted either if the child:

TABLE 24

NUMBER AND PROPORTION OF CHILDREN IN FOUR GRADE BLOCKS
SHOWING GAIN, STABILITY, OR LOSS FROM YEAR 1 TO YEAR 2 ON MASTERY OF THREE CONCEPT USES

Grade Group		USES: Principle Gain 0→1	Principle Stable 0→0	Principle Stable 1→1	Principle Loss 1→0	Problem Solving Gain 0→1	Problem Solving Stable 0→0	Problem Solving Stable 1→1	Problem Solving Loss 1→0	Supraordinate-Subordinate Gain 0→1	Supraordinate-Subordinate Stable 0→0	Supraordinate-Subordinate Stable 1→1	Supraordinate-Subordinate Loss 1→0
Block 1 (n = 82)	No.	0	82	0	0	0	82	0	0	0	82	0	0
	Prop.	.00	1.00	.00	.00	.00	1.00	.00	.00	.00	1.00	.00	.00
Block 2 (n = 92)	No.	2	90	0	0	13	79	0	0	14	75	0	3
	Prop.	.02	.98	.00	.00	.14	.86	.00	.00	.15	.82	.00	.03
Block 3 (n = 91)	No.	15	66	6	4	33	57	1	0	12	71	2	6
	Prop.	.16	.73	.07	.04	.36	.63	.01	.00	.13	.78	.02	.07
Block 4 (n = 86)	No.	11	26	39	10	29	25	29	3	25	38	18	5
	Prop.	.13	.30	.45	.12	.34	.29	.34	.03	.29	.44	.21	.06
All Grades (N = 351)	No.	28	264	45	14	75	243	30	3	51	266	20	14
	Prop.	.08	.75	.13	.04	.21	.69	.09	.01	.15	.76	.06	.04

KEY:

Gain : 0→1 = Fail year 1, pass year 2 Stable : 1→1 = Pass year 1, pass year 2
Stable : 0→0 = Fail year 1, fail year 2 Loss : 1→0 = Pass year 1, fail year 2

(1) did not master the subtest either year or (2) mastered the subtest both years. A performance loss occurred if the child mastered the subtest year 1 but failed to do so year 2.

Examination of row one in Table 24 reveals that neither as kindergarteners nor as first graders were any Block 1 children able to master any of the three concept uses in terms of the pass/fail criteria. Data presented for Block 2 children begin to reflect some gains in mastery from first to second assessments on problem solving and supraordinate-subordinate, although 98 percent of Block 2 children were still unable to master the principles subtest in either 1973 or 1974. Block 3 children made some notable gains as seventh graders in mastery of uses over their performance as sixth graders, particularly on problem solving. The largest percentage of children in Block 3, however, failed each of the concept uses both years. In addition, four percent of these children failed to master principles and seven percent failed to master supraordinate-subordinate after doing so at the initial assessment. Nevertheless, in Block 3 we observe for the first time a small number of children who mastered the uses of the equilateral triangle concept in both years of longitudinal assessment. The largest proportion of Block 4 children were either able to master the concept uses at first and second assessments or did so by year 2. In Block 4 only 30 percent of the children failed to master principles both years, 29 percent similarly failed to master problem solving, and 44 percent did not meet criterion for mastery of the supraordinate-subordinate subtest either year. In this block, we also find that 12 percent of the children mastered principles year 1 but not year 2, 3 percent lost mastery of problem solving, and 6 percent, supraordinate-subordinate.

The bottom row of Table 24 presents these data combined across blocks. The percentage of children showing loss of mastery from 1973 to 1974 was quite small for each of the uses. Percentages of all children who were unable to master the uses subtests either year 1 or year 2 were fairly large: 75 percent showed unchanged inability to master principles; 69 percent, problem solving; and 76 percent, supraordinate-subordinate. Children showed greatest mastery gains from 1973 to 1974 on problem solving (21 percent), next on supraordinate-subordinate (15 percent), and least on principles (8 percent). Combining the children who gained in mastery from year 1 to year 2 with the children who fully mastered the uses subtests both years of assessment shows that 30 percent of the longitudinal sample (105 children) mastered problem solving by or before year 2; 21 percent (73 children) mastered principles by or before year 2; 20 percent (71 children) mastered supraordinate-subordinate in both years or by year 2.

In summary, prediction eight receives support from these descriptive data. Moreover, with increasing grade block increasing numbers of children exhibited either (1) stable mastery of a use from year 1 to year 2 or (2) mastery by the 1974 assessment.

Charting Mastery of the Uses from Year 1 to Year 2 for Four Grade Group Blocks

The means and standard deviations for items correct on each concept use are presented in Table 25 for each of the four grade blocks. From these data, mean percentage of items correct can be computed (see Table 26) and the longitudinal performance on the three uses subtests can be charted and compared. The shape of the developmental curves for the uses is preliminary at this point in the longitudinal study since data are presently available for 1973 and 1974.

TABLE 25

MEANS AND STANDARD DEVIATIONS OF ITEMS CORRECT ON EACH OF THREE CONCEPT USES FOR CHILDREN IN FOUR GRADE BLOCKS

Total Items =		Principle 5 pairs		Problem Solving 5		Supraordinate-Subordinate 4 pairs	
		M	S.D.	M	S.D.	M	S.D.
Block 1 (n = 82)	Year 1	0.00	0.00	0.00	0.00	0.00	0.00
	Year 2	0.00	0.00	0.06	0.24	0.34	0.53
Block 2 (n = 92)	Year 1	0.00	0.00	0.99	0.88	0.88	0.84
	Year 2	0.97	1.05	1.55	1.03	1.44	1.01
Block 3 (n = 91)	Year 1	1.70	1.26	1.69	0.87	1.11	0.97
	Year 2	2.31	1.54	2.42	1.17	1.42	1.02
Block 4 (n = 86)	Year 1	3.49	1.34	2.90	1.22	1.70	1.15
	Year 2	3.50	1.61	3.58	1.46	2.38	1.44

TABLE 26

MEAN PERCENTAGE OF ITEMS CORRECT ON
THREE CONCEPT USES FOR FOUR GRADE BLOCKS

Block	Grade	Prin	Prob Solv	SS
Block 1 (N = 82)	K	0.0	0.0	0.0
	1	0.0	1.2	8.5
Block 2 (N = 92)	3	0.0	19.8	22.0
	4	19.4	31.0	36.0
Block 3 (N = 91)	6	34.0	33.8	27.7
	7	46.2	48.4	35.5
Block 4 (N = 86)	9	69.8	58.0	42.5
	10	70.0	71.6	59.5

Inspection of data presented in the columns of Table 25 reveals a consistent increase in mean number of items passed both within and across grade blocks (a combination of longitudinal and cross-sectional data). The only uses subtest in which reversals to consistent progression occur is supraordinate-subordinate; the mean number of items correct obtained by Block 2-year 2 children and Block 3 children are the only exceptions to steady increments in item performance. Examination of the percentages shown in Table 26 discloses similar trends.

Figure 5 constructs the developmental curves, based on mean percentage of items correct, for each of the three concept uses. This figure indicates, for the younger children, a slower mastery of principles items, compared to mastery of the other two uses subtest items. Mastery of problem solving items seems to occur somewhat earlier; but after sixth grade the curve parallels fairly closely that for principles. The curve representing mastery of the supraordinate-subordinate subtest items accelerates the earliest and is initially the steepest; after sixth grade, however, the curve falls below the curves for principles and problem solving.

These curves are based on a minimum of longitudinal measurement; consequently, these trends are only preliminary and approximate indicators of developmental changes in the ability to use the equilateral triangle concept. As measurement in the longitudinal program continues, future curves charting development of the three concept uses will more accurately reflect age changes in performance on the uses of this particular concept, as well as for others.

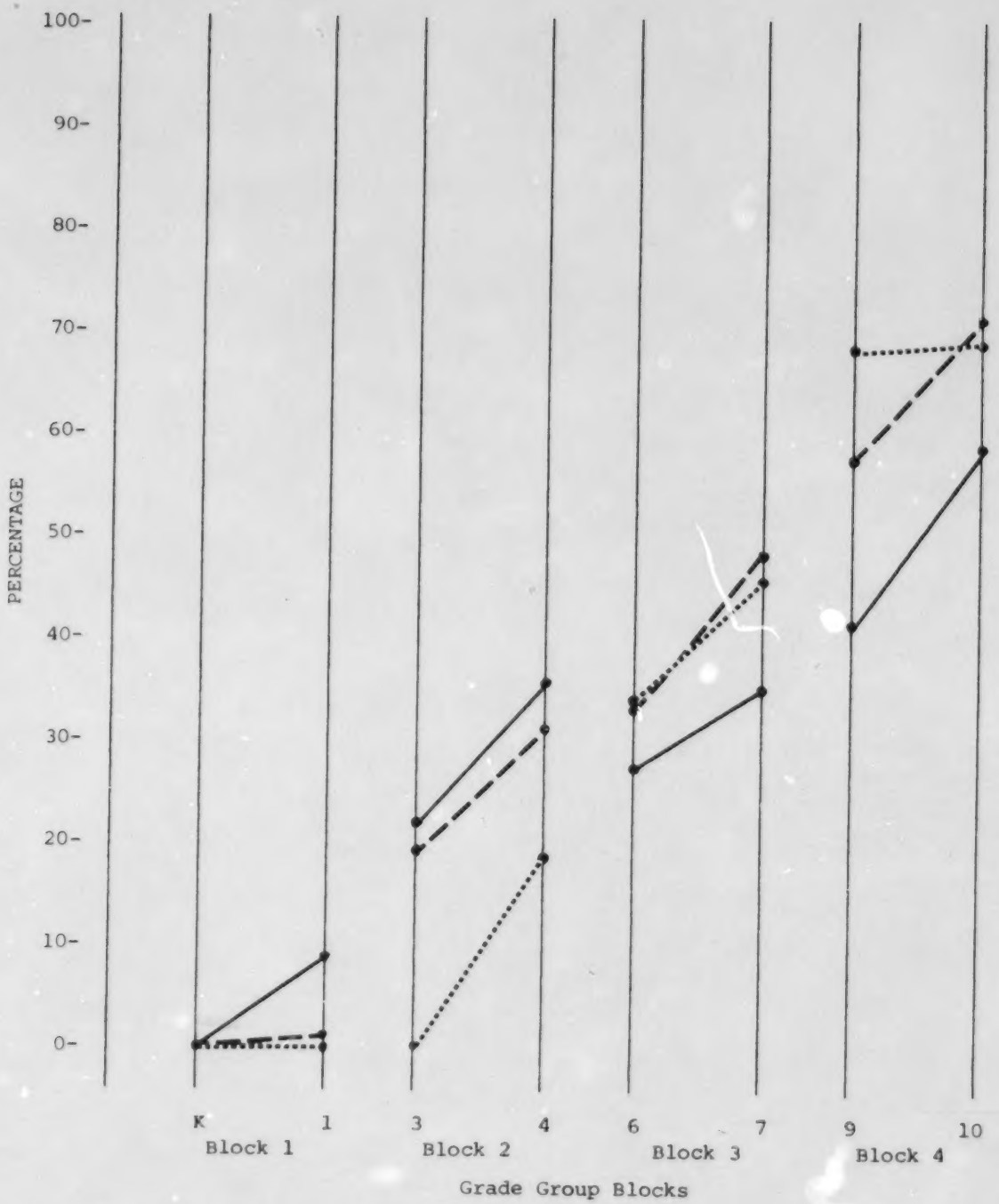

Figure 5. Mean percentage of items correct on three concept uses for four grade blocks: year 1 and year 2 of longitudinal assessment..

——— Supraordinate-Subordinate
– – – – Problem Solving
..... Principle

For each grade block separately, Figure 6 constructs curves from the row percentages in Table 26, and shows item performances on each use at each year of longitudinal assessment. These curves graphically document the differences in mastery of uses items from 1973 to 1974. For Block 1 and Block 2 children items on the principles subtest appear to have been the most difficult, relative to the other two uses, whereas for Block 3 and Block 4 children supraordinate-subordinate items were relatively the more difficult. In Block 1 improvement was greatest from year 1 to year 2 on supraordinate-subordinate items; in Blocks 2 and 3 improvement in number of items correct occurred quite uniformly across all uses subtests. In Block 4 little gain in number of principles items occurred from year 1 to year 2, but improved item performance in year 2 is apparent on problem solving and supraordinate-subordinate subtests.

PROGRESS IN MASTERY OF THE LABELS

One of the major propositions of the CLD model is that acquisition of the labels of a concept and its attributes is closely related to concept development and use. It was predicted that as each grade group is followed during longitudinal assessment, percentages of vocabulary items correct will increase. Table 19, presented earlier, shows mean number of vocabulary items correct for each grade block for each year of assessment Figure 3 similarly shows the curve for vocabulary acquisition based on mean percentage of vocabulary items passed. Referring back to Table 19, we see that within and across grade blocks there was a steady increase in mean number of correct vocabulary items. Close inspection reveals that within blocks the largest spurt in acquisition occurred in Block 1; an average of 1.16 items was passed in 1973 compared to a mean of 2.52 in

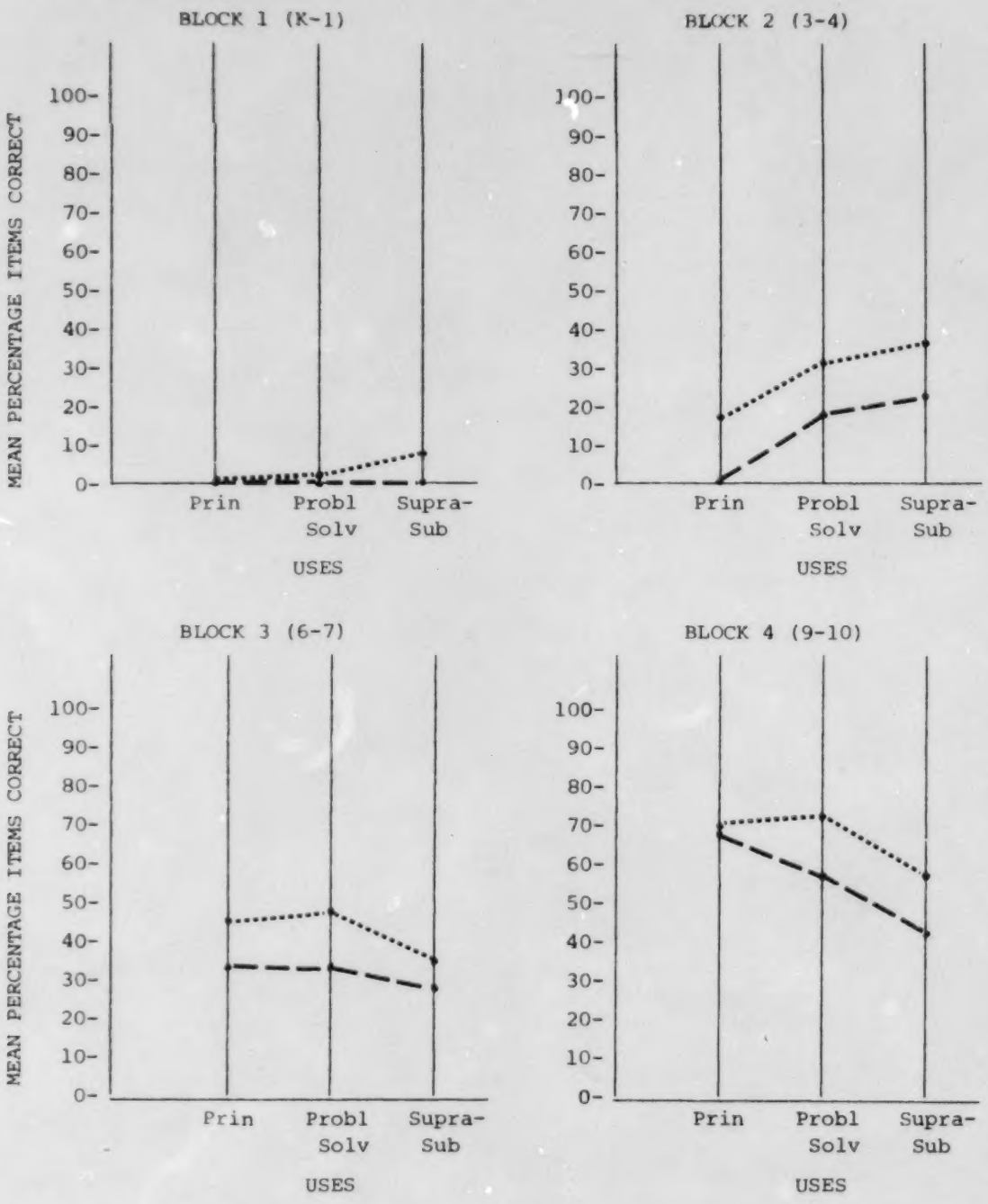

Figure 6. Mean percentage of items correct on three concept uses for each grade block: year 1 and year 2 of longitudinal assessment.

– – – – – 1973
..... 1974

1974. Block 2 children obtained a mean of 2.94 vocabulary items correct at the first assessment and 3.71 at the second. Block 3 children obtained a mean of 4.55 items year 1 and 5.18 year 2. The smallest increment from year 1 to year 2 occurred in Block 4 children; as ninth graders they obtained a mean of 5.80 items and as tenth graders, 5.91 items. Clearly, with each year of longitudinal assessment acquisition of the labels of the concept equilateral triangle, and its attributes, increased and no reversals to the predicted direction were exhibited.

The final prediction to be evaluated in this chapter stated that within each grade block, children gaining in number of vocabulary items from year 1 to year 2, will also gain in number of uses items passed. Of the total number of children in each block gaining in vocabulary items, Table 27 shows the number and proportion gaining, remaining the same, or losing combined uses items from year 1 to year 2. For example, of the 51 Block 1 children gaining in vocabulary items, 17 (33 percent) also gained on combined uses items and 34 (66 percent) did not differ in performance on uses items from year 1 to year 2. These results reflect an overall inability of the youngest children to master the uses subtests, as noted earlier. In contrast, of the 46 Block 2 children who gained vocabulary items, 84 percent also gained in combined uses items passed. Similarly, 63 percent of the total 51 Block 3 children gaining vocabulary items gained in combined uses items from 1973 to 1974 and 73 percent of the total 33 Block 4 children gaining in vocabulary also gained in combined uses items passed. Across all grade blocks, 181 of the total 351 children gained vocabulary items and of these children, 62 percent also gained in number of items passed on the combined uses subtests. Twenty-seven percent passed the same number of combined uses items

TABLE 27

RELATIONSHIP BETWEEN GAIN IN VOCABULARY ITEMS FROM YEAR 1 TO YEAR 2 AND PERFORMANCE ON COMBINED USES ITEMS: NUMBER AND PROPORTION GAINING, REMAINING STABLE OR LOSING USES ITEMS

	Performance on Combined Uses Items		
	Gain Year 2	Same Year 1 and 2	Loss Year 2
Block 1 (n = 82)			
N Gaining in Vocab. Items = 51			
N	17	34	0
Proportion	.33	.66	.00
Block 2 (n = 92)			
N Gaining in Vocab. Items = 46			
N	39	3	4
Proportion	.84	.07	.09
Block 3 (n = 91)			
N Gaining in Vocab. Items = 51			
N	32	9	10
Proportion	.63	.18	.20
Block 4 (n = 86)			
N Gaining in Vocab. Items = 33			
N	24	2	7
Proportion	.73	.06	.21
All Grades (N = 351)			
N Gaining in Vocab. Items = 181			
N	112	48	21
Proportion	.62	.27	.12

year 1 and year 2, although they gained vocabulary items; 12 percent passed fewer combined uses items year 2 than year 1.

A single Chi-square test, conducted on combined grade group data, confirmed that of the 181 children gaining in vocabulary from year 1 to year 2, a significantly greater proportion ($p < .01$) gained in uses items passed year 2 compared to those passing the same number of uses items or losing uses items from year 1 to year 2 (Chi-square = 108.61, d.f. = 2). Thus for the total 181 children gaining in vocabulary, the distribution of gain, stability, or loss in uses items performance deviated significantly from a chance or uniform distribution.

To review briefly, the longitudinal data in general provide good support for the predictions regarding acquisition of the labels of the equilateral triangle concept and its relation to ability to use the concept.

IV

LONGITUDINAL RESULTS OF CLD ASSESSMENT SERIES I: EQUILATERAL TRIANGLE (WATERTOWN)

OVERVIEW

A brief description of the child population composing a second longitudinal sample in Watertown precedes a brief descriptive evaluation of the assessment data collected in 1973 and 1974. The data are presented and evaluated in terms of the evidence they provide for the major longitudinal predictions derived from the CLD model. It will be recalled from Chapter II that the Watertown sample was not the primary focus of the longitudinal study; therefore, no control groups were included. Nevertheless, the data were regarded as a useful replication and check on the validity of the major longitudinal findings reported in Chapter III.

CHILD POPULATION

Table 28 presents a summary description, according to sex and age, of the 275 children who participated in the longitudinal assessment. These data are provided only for year 2, since the same information for year 1 requires only a subtraction of 12 months. Children in the longitudinal sample will hereafter be referred to as belonging to one of four grade blocks. Block 1 consisted of 48 children tested in year 1 (1973) as kindergarteners and again in year 2 (1974) as first graders. Similary, in Block 2 there were

TABLE 28

LONGITUDINAL CORE-YEAR 2: TOTAL NUMBER OF CHILDREN, MEAN AGE AND AGE RANGE AT EACH GRADE

Grade	Number	Mean Age (in years and months)	Age Range (in years and months)
1	Total 48	6 - 10	6 - 3 to 7 - 5
	Boys 28	6 - 10	6 - 3 to 7 - 5
	Girls 20	6 - 9	6 - 3 to 7 - 3
4	Total 71	9 - 9	9 - 2 to 10 - 4
	Boys 44	9 - 10	9 - 4 to 10 - 4
	Girls 27	9 - 8	9 - 2 to 10 - 4
7	Total 78	12 - 9	12 - 2 to 13 - 5
	Boys 32	12 - 10	12 - 2 to 13 - 5
	Girls 46	12 - 9	12 - 2 to 13 - 5
10	Total 78	15 - 7	15 - 1 to 16 - 5
	Boys 38	15 - 7	15 - 1 to 16 - 3
	Girls 40	15 - 6	15 - 1 to 16 - 5

71 children, tested as third graders and a year later as fourth graders. In Block 3, 78 children participated (as sixth graders year 1 and as seventh graders year 2) and in Block 4, 78 children took part (as ninth graders and again as tenth graders). Table 28 shows that number of boys and girls in each block was somewhat unequal except in Block 4. The total age range of the children within each grade varied from 14 months in Blocks 1 and 2 to 16 months in Block 4. Mean ages of boys and girls within grades were very close.

CRITERIA FOR FULL ATTAINMENT

The criteria established for determining full attainment of each level and use of the equilateral triangle battery as used in Watertown were identical to those used in Beloit and may be reviewed in Table 5, Chapter III.

CONFORMITY TO THE PREDICTED INVARIANT SEQUENCE

Information presented in Table 29 permits an examination of the contingent relation between conformity to the predicted invariant sequence in the first and second years of longitudinal assessment. These data are critical to an evaluation of the first and major prediction asserting that conformity to the five acceptable patterns will consistently be observed as children are tested longitudinally.

The number and proportion of each grade block following and not following acceptable patterns in year 2 are shown as a function of following and not following acceptable patterns in year 1. For example, Table 29

TABLE 29

NUMBER AND PROPORTION OF CHILDREN IN EACH GRADE BLOCK CONFORMING AND NONCONFORMING TO PREDICTED INVARIANT SEQUENCE IN 1974 AS A FUNCTION OF CONFORMING OR NONCONFORMING IN 1973

	Conform 1973 (year 1)					Nonconform 1973 (year 1)				
	Block					Block				
	1	2	3	4	Total	1	2	3	4	Total
N =	39	67	70	76	252	9	4	8	2	23
Conform 1974 (year 2)	38	62	67	68	235	8	3	7	1	19
	.97	.92	.95	.89	.85	.89	.75	.88	.50	.07
Nonconform 1974 (year 2)	1	5	3	8	17	1	1	1	1	4
	.02	.07	.04	.11	.06	.11	.25	.13	.50	.01

shows that in Block 1 (referring to the 48 children who were in kindergarten year 1, first grade year 2) 39 children conformed to the model at the time of initial assessment. In year 2, 38 of these children (97 percent) conformed once again; 1 child did not. Table 29 also shows that in Block 1, nine children did not conform year 1; in year 2, eight of these children followed acceptable patterns. As another example, we may inspect the data presented for the 78 children in Block 4 (ninth graders year 1, tenth graders year 2). Examination reveals that 76 children conformed the first year of assessment and of these, 68 were consistent in following acceptable patterns the second year. Eight of the children who conformed as ninth graders failed to do so as tenth graders. Two children in Block 4 did not conform year 1; in year 2 one of these continued to exhibit an unacceptable pattern. Across all grade blocks, Table 29 indicates that 252 children (92 percent) conformed at the time of the first assessment and 254 (92 percent) followed acceptable patterns at the time of the second assessment. Of the 275 children in the longitudinal sample, 235 or 85 percent consistently conformed to the predicted invariant sequence. Twenty-three children, or eight percent, did not conform year 1; all but four of these children did so by year 2. Four children (one from each block) did not conform during either the first or second assessments. More problematic are the 17 children (six percent of the total sample) who followed acceptable patterns year 1 but failed to conform year 2. As shown in Table 29, these children were distributed as follows: Block 1, one child; Block 2, five children; Block 3, three children; and Block 4, eight children.

In order to examine more closely the performances of the 17 children who were non-conformers only in year 2 and the 4 children who did not conform

in either year, Table 30 presents the specific patterns of exception into which these 21 children fell year 2 and the number of items correct on those subtests for which mastery criterion was not reached. The two children in the unacceptable FPFF and FPPP patterns passed six of the eight concrete subtest items, and consequently came very close to meeting the criterion for mastery. The single child in the FPPF pattern fell somewhat farther short of meeting criterion for mastery on the concrete subtest. The three children who did not meet mastery criterion for the identity subtest just barely missed that criterion. The majority (15) of the nonconforming children fell into the unacceptable PPFP pattern. Table 30 shows that 12 of these children barely missed reaching criterion for attainment of the classificatory level, although 1 child failed all items on this subtest.

From this detailed examination it is clear that most of the 21 children who were nonconformers year 2 came very close to meeting criterion on subtests that should have been passed according to the CLD model, since higher levels were mastered.

Data presented to this point have addressed the prediction of consistent conformity to the five acceptable patterns of mastery of the four concept levels. To review briefly, it was found that 92 percent of the longitudinal sample conformed to the predicted invariant sequence of concept attainment at the initial assessment, 92 percent conformed year 2, and 85 percent of the 275 children in the longitudinal sample consistently followed acceptable patterns of concept mastery over both years of assessment; these findings are interpreted as supportive of the first longitudinal prediction.

TABLE 30

FREQUENCIES OF SUBJECTS ACCORDING TO PATTERN OF EXCEPTION YEAR 2 AND ITEMS CORRECT AT EACH CONCEPT LEVEL NOT ATTAINED

N	Pattern of Exception Year 2	Number of Items Correct on Concrete Subtest (7 required)							
		0	1	2	3	4	5	6	7
1	FPFF							1	
1	FPPP							1	
1	FPPF					1			
		Number of Items Correct on Identity Subtest (7 required)							
		0	1	2	3	4	5	6	7
2	PFPF							2	
1	PFPP							1	
		Number of Items Correct on Classificatory Subtest (3 required)							
		0	1	2					
15	PPFP	1	2	12					

LONGITUDINAL ATTAINMENT OF THE FOUR CONCEPT LEVELS

The present section will examine in detail attainment of each of the four concept levels during each year of assessment, especially as it reflects changes in children's conceptual development. First, we consider longitudinal attainment of concept levels in conjunction with conformity to the five acceptable patterns of attainment. Then, the data are examined relating to highest level of concept attainment at the time of initial assessment in comparison with highest level of concept mastery the following year. These latter data provide longitudinal information regarding age changes in conceptual development and address the fourth prediction: children should master the equilateral triangle concept at a higher level than the previous year or, equally acceptable, at the same level as the previous year. This prediction is, of course, critical to the invariant sequence prescribed by the model.

Longitudinal Attainment of Equilateral Triangle and Conformity to the Model

Children in each grade block of the longitudinal sample can be evaluated on two performance dimensions simultaneously: (1) conforming or not conforming to the five acceptable patterns of concept attainment each year of assessment and (2) level of concept attainment year 2 relative to level of attainment at initial assessment: higher, same, or lower. As observed in an earlier section, 85 percent of the children consistently conformed to acceptable patterns over both years of testing. But it is possible for a child to follow acceptable patterns at each assessment and yet fully attain at a lower concept level year 2 in comparison with year 1. For example, a child exhibiting the PPPF pattern year 1 and the PPFF year 2 would obviously

have attained to the classificatory level initially, but only to identity the following year. It is also possible for a child to follow unacceptable patterns both years (or any single year) and yet attain at a higher level year 2 compared to year 1. For example, a child exhibiting the FPFF pattern year 1 and the FPPF pattern year 2 would have fully mastered at a higher level at the time of the second assessment.

Table 31 presents the number and proportion of children in each grade block who fall into one of the 12 possible categories that combine conformity to acceptable patterns and level of attainment year 2 in comparison with that of year 1. Column one indicates conforming or not conforming to one of the five acceptable patterns of attainment year 1, column two indicates conforming or not conforming year 2, and column three indicates whether level of mastery year 2 was higher, the same or lower than level of mastery year 1. Bear in mind that these data do not yet focus on the specific levels of concept attainment: concrete, identity, classificatory, and formal. At this point we are only concerned with year 2 level of mastery relative to that of year 1.

The first row entries in Table 31 show that across all grades 66 children conformed both years and at a higher level of mastery the second year. Entries in the fifth row of the table show that across all grades 145 children conformed both years and at the same level of mastery year 2 as that attained year 1. Therefore, 211 children (77 percent of the longitudinal sample) consistently conformed to the model and attained at the same or at higher levels compared to year 1.

Combining the first two rows of Table 31 indicates that 73 children (27 percent) attained at a higher level of concept mastery compared to

TABLE 31

NUMBER AND PROPORTION OF CHILDREN IN FOUR GRADE BLOCKS WHO CONFORMED OR NOT YEAR 1, CONFORMED OR NOT YEAR 2 AND LEVEL OF CONCEPT ATTAINMENT YEAR 2 COMPARED TO YEAR 1

Sequence: Conformity to Model Year 1	Year 2	Year 2 level Attainment Compared to Yr. 1	Grade Group Block: Block 1 (n = 48)	Block 2 (n = 71)	Block 3 (n = 78)	Block 4 (n = 78)	All Grades (N = 275)
C -	C -	Higher:	20 .42	21 .30	19 .24	6 .08	66 .24
NC -	C -	Higher:	3 .06	0 .00	3 .04	1 .01	7 .02
C -	NC -	Higher:	1 .02	4 .06	1 .01	1 .01	7 .02
NC -	NC -	Higher:	0 .00	0 .00	0 .00	0 .00	0 .00
C -	C -	Same:	14 .29	35 .49	39 .50	57 .73	145 .53
NC -	C -	Same:	5 .10	3 .04	2 .02	0 .00	10 .04
C -	NC -	Same:	0 .00	1 .01	2 .02	7 .09	10 .04

Continued on next page.

TABLE 31, continued.

Conformity to Model Year 1	Sequence Year 2	Year 2 level Attainment Compared to Yr. 1	Grade Group Block Block 1 (n = 48)	Block 2 (n = 71)	Block 3 (n = 78)	Block 4 (n = 78)	All Grades (N = 275)
NC -	NC -	Same:	1 .02	1 .01	1 .01	1 .01	4 .01
C -	C -	Lower:	4 .08	5 .07	9 .12	5 .06	23 .08
NC -	C -	Lower:	0 .00	0 .00	2 .02	0 .00	2 .01
C -	NC -	Lower:	0 .00	1 .01	0 .00	0 .00	1 .00
NC -	NC -	Lower:	0 .00	0 .00	0 .00	0 .00	0 .00

Key: C = Conforming to model = following one of the 5 acceptable patterns of attainment
NC = Nonconforming to model = following one of the 11 non-acceptable patterns of attainment

the previous year and in an acceptable pattern by or before year 2. Similarly, by combining rows five and six, 155 children (56 percent) were observed to attain at the same level of mastery as the previous year and in an acceptable pattern by or before year 2. Altogether then, 228 children (83 percent) attained at the same level or increased in level of attainment the second year of assessment and in one of the five acceptable patterns by year 2.

Categories represented by rows three and four show that seven children (two percent) did not conform to the model either in both years or in year 2 but attained to a higher level of mastery year 2 compared to year 1. Categories represented by rows seven and eight show that 14 children (five percent) did not conform to the model year 2 but attained at the same level of mastery as the previous year. Thus a total of 21 children (eight percent of the longitudinal sample) did not conform to the model the second year, or both years, but demonstrated concept mastery at the same level as the previous year or at a higher level. (In an earlier section item performances were examined for the 21 children who did not conform year 2 to one of the five acceptable patterns of concept mastery.)

Twenty-five children (nine percent of the sample) followed an acceptable pattern year 2, or both years, but at a lower level of mastery than the previous year (see rows nine and ten). One child showed both nonconformity to the model year 2 and a lower level of concept mastery than attained year 1.

Data in Table 31 also yield information about progress, stability, or loss in highest level of concept attainment over the first two years of longitudinal assessment. By collapsing the first four categories in this table we can determine the percentage of children who attained at a higher

level year 2 in comparison with the initial mastery level, regardless of whether or not attainment was in accord with acceptable patterns. Collapsing the middle four categories and the last four categories separately reveals the percentage of children who remained stable in mastery level from year 1 to year 2 and the percentage of children losing one or more levels from year 1 to year 2.

The data in Table 32 have been derived in this manner and provide a clear summary of the percentages of children within each block and across all blocks showing progress, stability and loss in highest level of mastery from year 1 to year 2. Of the entire longitudinal sample, 29 percent (80 children) attained a higher level the second year of assessment than that attained initially. Sixty-one percent of the sample (169 children) exhibited a level of concept mastery year 2 identical to that of year 1. Twenty-six children, or nine percent of the sample, fully attained at a lower concept level year 2 in comparison with year 1.

Thus, of the entire longitudinal sample, 249 children attained at the same level as the previous year or at higher levels. This finding indicates that 91 percent of the 275 children examined longitudinally performed in accord with the fourth prediction.

It is also instructive to examine the relative contributions of the four grade blocks to the total percentages of children showing gains, stability, or loss in level of mastery. In general, Table 32 shows that Blocks 1, 2, and 3 contained about equal percentages of children who progressed in level of concept mastery from first to second assessments; Block 4 (the oldest children) contained the greatest number of children remaining stable from first to second assessments in highest level of mastery.

TABLE 32

NUMBER AND PROPORTION OF CHILDREN IN FOUR GRADE GROUP BLOCKS SHOWING GAIN, STABILITY, OR LOSS IN CONCEPT ATTAINMENT FROM YEAR 1 TO YEAR 2

	Block 1 (n = 48)	Block 2 (n = 71)	Block 3 (n = 78)	Block 4 (n = 78)	All Grades (N = 275)
Gain of 1 or more levels yr. 2	24 .50	25 .35	23 .29	8 .10	80 .29
Stable - level of attainment same yr. 1 & yr. 2	20 .42	40 .56	44 .56	65 .83	169 .61
Loss of 1 or more levels yr. 2	4 .08	6 .08	11 .14	5 .06	26 .09

In contrast, children whose highest level of attainment was lower year 2 than year 1 were about equally distributed across all four grade blocks. In the next sections these findings will be explored in detail.

Highest Level of Concept Attainment Year 2 in Comparison with Year 1

To review briefly, 29 percent of the longitudinal sample gained in mastery level, 61 percent remained stable, and 9 percent lost one or more levels from first to second assessments. Moreover, the four grade blocks tended to contribute differentially to these percentages. Although this information is useful, a more critical analysis of the course of conceptual development can be discovered by examining the exact mastery performances from year 1 to year 2. The present section focuses on the particular sequence of highest mastery levels followed by children from year 1 to year 2 and provides more specific evidence for the fourth prediction.

The data presented in Table 33 permit precise examination of children's longitudinal performances in highest level of concept mastery from year 1 to year 2. These data now reveal why a preponderance of children in Block 4 fell into the "stable" category and what exact sequences of mastery were responsible for children who "progressed." The results are also suggestive of the typical or modal sequence of concept attainment from year 1 to year 2 for each of the grade blocks.

Table 33 presents the number and proportion of children in each grade block who followed various sequences of concept level attainment in terms of highest level of mastery year 1 and highest level of mastery year 2; consequently, the number of levels increased (or decreased) from first to second assessment can be determined, and appears in the first column of the table.

TABLE 33

NUMBER AND PROPORTION OF CHILDREN IN FOUR GRADE BLOCKS SHOWING HIGHEST LEVEL OF CONCEPT ATTAINMENT YEAR 1 AND YEAR 2

No. Levels Increased from Year 1 to Year 2	Highest Level of Attainment Year 1		Year 2	Block 1 (n = 48)	Block 2 (n = 71)	Block 3 (n = 78)	Block 4 (n = 78)	All Grades (N = 275)
0	Formal	→	Formal	0	9	33	62	104
				.00	.13	.42	.79	.38
+1	Classif.	→	Formal	0	18	18	7	43
				.00	.25	.23	.09	.16
+2	Identity	→	Formal	1	3	2	1	7
				.02	.04	.02	.01	.02
+3	Concrete	→	Formal	0	0	0	0	0
				.00	.00	.00	.00	.00
+4	No levels	→	Formal	0	0	0	0	0
				.00	.00	.00	.00	.00
0	Classif.	→	Classif.	16	27	11	3	57
				.33	.38	.14	.04	.21
+1	Identity	→	Classif.	14	4	3	0	21
				.29	.06	.04	.00	.08
+2	Concrete	→	Classif.	1	0	0	0	1
				.02	.00	.00	.00	.00
+3	No levels	→	Classif.	5	0	0	0	5
				.10	.00	.00	.00	.02

Continued on next page.

TABLE 33, continued.

No. Levels Increased from Year 1 to Year 2	Highest Level of Attainment Year 1		Year 2	Block 1 (n = 48)	Block 2 (n = 71)	Block 3 (n = 78)	Block 4 (n = 78)	All Grades (N = 275)
0	Identity	→	Identity	4 .08	4 .06	0 .00	0 .00	8 .03
+1	Concrete	→	Identity	1 .02	0 .00	0 .00	0 .00	1 .00
+2	No levels	→	Identity	2 .04	0 .00	0 .00	0 .00	2 .01
0	Concrete	→	Concrete	0 .00	0 .00	0 .00	0 .00	0 .00
+1	No levels	→	Concrete	0 .00	0 .00	0 .00	0 .00	0 .00
-	Loss of 1 or more levels yr. 2			4 .08	6 .08	11 .14	5 .06	26 .09

For the formal level attainers year 2, there existed five possible "routes" to attainment at the formal level in relation to mastery level year 1: formal to formal; classificatory to formal; identity to formal; concrete to formal; and finally, no levels fully mastered year 1 to formal level mastery year 2. Four possible sequential attainment routes were possible for those children attaining classificatory as their highest level year 2: classificatory to classificatory; identity to classificatory; concrete to classificatory; no levels to classificatory. The attainment routes for identity and concrete level attainment year 2 are similarly made explicit in Table 33. At the bottom of the table, the number and proportion of children in each grade block losing one or more levels are included.

a. Performance of all children combined across blocks. Children whose performance indicated stability, then, were those whose highest mastery level was at formal, at classificatory, at identity, or at concrete for both years of assessment. None of the 275 children passed no levels both years. Children whose performance indicated gains were, of course, those who attained at a higher level year 2 in comparison with mastery level year 1. Inspection reveals that a large number of children were stable (169 children, or 61 percent, as reported earlier). Now it can be determined that this result was largely due to those children who had attained to the highest level of concept mastery both years, reflecting a "ceiling effect" in concept attainment (104 children, or 38 percent of the total sample); 62 of the consistent formal level attainers were in Block 4 (or 79 percent of the oldest children). The next largest number of children showing stable attainment were at classificatory both years (57 children, or 21 percent). Eight children (3 percent of the total sample) remained at identity both years and no children attained concrete as their highest level both years.

Inspecting Table 33 for the distribution of children showing gains from year 1 to year 2 in highest level of attainment shows that the largest number of children making gains progressed from classificatory to formal--43 children, or 16 percent of the total sample. The next largest percentage is due to the children who progressed from identity to classificatory (21 children, or 8 percent of the total sample). Only one child (in Block 1) moved from concrete to identity. All of the children just described (65 children, or 24 percent) progressed in concept mastery from first to second assessments by gaining one higher concept level.

If the 169 children whose highest attainment levels both years were the same are combined with the 65 children whose highest attainment level year 2 was one level higher than that of year 1, we find that 234 children, or 85 percent of the longitudinal sample attained at the same level as the previous year or at the next higher level (one concept level higher than the attained year 1).

Disregarding for the present those children who lost one or more levels from year 1 to year 2, it can be observed that the remainder of the longitudinal sample progressed in mastery by gaining two or more levels from year 1 to year 2. In order of frequency, examination of Table 16 reveals that seven children (two percent) gained from identity to formal (two levels gained); five children (two percent) gained from no levels to classificatory (three levels gained); two children (one percent) gained from no levels mastered year 1 to the identity level year 2 (two levels gained). A single child gained from concrete year 1 to classificatory the second year of assessment (two levels gained). Altogether then, a total of 15 children (five percent

of the longitudinal sample) progressed in level of mastery by gaining more than a single concept level.

Although the majority of the children who progressed in level of attainment from year 1 to year 2 did so by gaining one concept level, gaining two or more levels may have been due to a variety of factors. For these children, the testing interval of one year may have been too great to register separately the successive gains in attainment level. Or, a child may have just barely missed meeting the pass/fail criterion for attainment at a particular level at the time of initial assessment (due to errors of measurement; criterion stringency). Performance the following year might then reflect attainment of that particular level as well as the next higher level. Or, the child might for some reason have received explicit instruction in the period intervening between first and second assessments sufficient to accelerate the child's mastery two or more levels beyond that exhibited at initial testing.

In summary, more than half of the 169 children who showed no progress in highest level of mastery from year 1 to year 2 were at formal both years (a ceiling in performance); 65 children gained one concept level from year 1 to year 2, and 15 children gained two or more levels from first to second assessments. These more specific findings are viewed as further strong support for the fourth prediction stating that a child will master a concept at the same level as the previous year, or at higher levels.

b. Performances of each grade block. Table 33 also permits examination of performances of the individual blocks of the longitudinal sample. Children who were kindergarteners year 1 and first graders year 2 (Block 1) were distributed over 8 of the 14 possible highest level of attainment

sequences shown in the table (disregarding for the present children who lost one or more levels). Children who were third graders year 1 and fourth graders year 2 (Block 2) were distributed over 6 of the 14 possible sequences; children in Block 3, sixth graders who became seventh graders year 2, were distributed over 5 of the 14 sequences and children who were ninth graders year 1 and tenth graders year 2 (Block 4) appear in only 4 of the sequences. Thus, with increasing grade fewer of the possible attainment sequences were followed--performance became decreasingly variable.

We can now also discern the modal sequence of concept attainment followed by each of the four blocks. Consider the highest attainment level sequences observed from first to second assessments in Block 1. The largest percentage of the youngest children were at classificatory both years (33 percent). More than half of the 48 Block 1 children either were at classificatory both years or progressed from identity to classificatory. The next single largest percentage of children gained to classificatory from no levels mastered year 1 (ten percent). The remaining Block 1 children were distributed fairly evenly over five of the remaining attainment sequences.

The largest single percentage of children in Block 2 were at classificatory both years of assessment (38 percent). In addition, a third of the 71 children in this block had attained to the formal level both years or demonstrated formal level mastery by year 2.

The modal attainment sequence observed in Block 3 children was stable attainment at the formal level both years (42 percent of the 78 children). The next largest percentage of children gained to formal year 2 from classificatory year 1 (23 percent). Fourteen percent of the children in Block 3 were also stable at classificatory both years.

Among the 78 children in Block 4, 79 percent were at formal both years of assessment. Nine percent gained to formal year 2 from classificatory year 1. Only four percent of the oldest children remained at classificatory both years.

As Table 33 shows, nine percent of the longitudinal sample attained at a lower level of mastery year 2 in comparison with year 1. All grade blocks contributed to this small percentage, although the largest number of children were in Block 3.

RELATION BETWEEN FULL ATTAINMENT OF THE VARIOUS LEVELS BY YEAR 2 AND FULL MASTERY OF THE USES

The fifth prediction derived from the CLD model specifies that individuals who have attained a concept only to the concrete or to the identity level by the second year of longitudinal assessment may be able to use that concept in cognizing simple perceptual relations among concepts and in solving simple problems of a perceptual kind but that they will not be able to use the concept in understanding supraordinate-subordinate relations, understanding principles, or in solving more complex problems. An evaluation of this prediction is possible from data shown in Table 34.

This table presents, for each group of children whose highest level of concept attainment year 1 and year 2 was as indicated at the left of the table, the number and proportion of children within each block passing each of the three concept uses. Data presented earlier revealed that no children attained concrete as their highest level year 2 or remained at that level of mastery from year 1 to year 2. However, three children (from Block 1 as Table 34 shows) gained to identity as their highest level of mastery. year 2; none of these children demonstrated mastery of any of the uses.

TABLE 34

RELATIONSHIP BETWEEN HIGHEST LEVEL OF CONCEPT ATTAINMENT
FROM YEAR 1 TO YEAR 2 AND MASTERY OF THE USES YEAR 2

	Block 1			Block 2			Block 3			Block 4			All Grades		
Highest Level	Prin	Prob Solv	Supra Sub	Prin	Prob Solv	Supra Sub	Prin	Prob Solv	Supra Sub	Prin	Prob Solv	Supra Sub	Prin	Prob Solv	Supra Sub
At Formal Yr. 1 and Yr. 2															
N at Level	0			9			33			62			104		
N Pass Use	0	0	0	0	1	3	18	13	20	47	46	31	65	60	54
Proportion	.00	.00	.00	.00	.11	.33	.55	.39	.61	.76	.74	.50	.63	.58	.52
Gain to Formal Yr. 2															
N at Level	1			21			20			8			50		
N Pass Use	0	0	0	2	4	5	4	10	7	2	5	1	8	19	13
Proportion	.00	.00	.00	.10	.19	.24	.20	.50	.35	.25	.63	.12	.16	.38	.26
Gain to Formal Yr. 2 from Classif. Yr. 1															
N at Level	0			18			18			7			43		
N Pass Use	0	0	0	2	3	8	2	9	6	2	5	1	6	17	15
Proportion	.00	.00	.00	.11	.17	.44	.11	.50	.33	.29	.71	.14	.14	.40	.35

Continued on next page.

TABLE 34, continued.

Highest Level	Block 1			Block 2			Block 3			Block 4			All Grades		
	Prin	Prob Solv	Supra Sub	Prin	Prob Solv	Supra Sub	Prin	Prob Solv	Supra Sub	Prin	Prob Solv	Supra Sub	Prin	Prob Solv	Supra Sub
At Classif. Yr. 1 and Yr. 2															
N at Level	16			27			11			3			57		
N Pass Use	0	0	2	1	4	9	0	1	1	1	1	1	2	6	11
Proportion	.00	.00	.13	.04	.15	.33	.00	.09	.09	.33	.33	.33	.04	.11	.19
Gain to Classif. Yr. 2															
N at Level	20			4			3			0			27		
N Pass Use	0	0	1	0	2	0	0	0	0	0	0	0	0	2	1
Proportion	.00	.00	.05	.00	.50	.00	.00	.00	.00	.00	.00	.00	.00	.07	.04
At Identity Yr. 1 and Yr. 2															
N at Level	4			4			0			0			8		
N Pass Use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Proportion	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

Continued on next page.

TABLE 34, continued.

Highest Level	Block 1			Block 2			Block 3			Block 4			All Grades		
	Prin	Prob Solv	Supra Sub	Prin	Prob Solv	Supra Sub	Prin	Prob Solv	Supra Sub	Prin	Prob Solv	Supra Sub	Prin	Prob Solv	Supra Sub
Gain to Identity Yr. 2															
N at Level	3			0			0			0			3		
N Pass Use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Proportion	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Loss of 1 or more Levels Yr. 2															
N at Level	4			6			11			5			26		
N Pass Use	0	0	0	0	1	1	1	3	0	1	2	1	2	6	2
Proportion	.00	.00	.00	.00	.17	.17	.09	.27	.00	.20	.40	.20	.08	.23	.08

Eight children were at identity both years of assessment and of these none met criterion for mastery on any uses subtests. It seems very clear, then, that the fifth prediction was borne out by these data.

The sixth longitudinal prediction deals with the expectation of superior performance on the uses subtests by children attaining at the formal level by or before year 2 compared with those attaining at the classificatory level by or before year 2. Table 34 presents the number and proportion of children mastering each of the uses as a function of: (1) their attainment of the formal level both years; (2) gain to formal by year 2; (3) attainment of classificatory both years; and (4) gain to classificatory by year 2. Combining the two groups of formal level attainers across all blocks results in 154 children attaining to the formal level by or before year 2 and combining the two groups of classificatory level attainers results in 84 children attaining to this level by or before year 2. Among the 154 formal level attainers, we find that 73 children mastered the principles subtest, 79 the problem solving subtest, and 67 the supraordinate-subordinate subtest. In contrast, among the 84 classificatory level attainers, 2 passed principles, 8, problem solving, and 12, supraordinate-subordinate.

Chi-square tests confirmed a statistically significant advantage (beyond the .001 level) for children attaining at the formal level when compared to those attaining at the classificatory level [Chi-square = 51.05, principles; 40.89, problem solving; 20.93, supraordinate-subordinate (d.f. = 1)].

A more specific prediction regarding performance on the uses by formal level attainers in comparison with classificatory level attainers focuses only on the children whose highest level of attainment was at classificatory year 1 and who attained to formal year 2; the comparison group is represented

by the children whose highest level of attainment was at classificatory both years 1 and 2. These two groups of children are also isolated in Table 34. Inspection shows that 57 children, across all blocks, attained classificatory as their highest level both years; 43 children gained from classificatory as their highest level year 1 to formal year 2. Of the 43 children progressing from classificatory to formal, 6 fully mastered the principles subtest; 17 problem solving; 15 supraordinate-subordinate. Of the 57 children remaining at classificatory both years, 2 mastered principles, 6 mastered problem solving and 11, supraordinate-subordinate. Chi-square tests confirmed, with statistical significance ($p < .01$), superior performance only on the problem solving subtest for children gaining to formal year 2 from classificatory year 1 [Chi-square = 11.65, problem solving (d.f. = 1)].

These results generally support prediction six and attest to the fact that, when compared with attainment at the classificatory level, attainment of a concept at the formal level does have a facilitative effect on ability to use the concept.

MASTERY OF THE THREE CONCEPT USES

The present section is concerned with age changes in mastery of the principles, problem solving, and supraordinate-subordinate subtests. Table 35 is organized to show the number and proportion of children in each grade group block who gained, remained unchanged, or lost from year 1 to year 2 in meeting criteria for full mastery of each concept use. Gain in mastery was demonstrated if the child failed to meet mastery criteria year 1 but did so year 2. Stable performance resulted either if the child: (1) did not master the subtest either year or (2) mastered the subtest both

TABLE 35

NUMBER AND PROPORTION OF CHILDREN IN FOUR GRADE GROUP BLOCKS
SHOWING GAIN, STABILITY, OR LOSS FROM YEAR 1 TO YEAR 2 ON MASTERY OF THREE CONCEPT USES

Grade Group		USES: Principle Gain 0→1	Principle Stable 0→0	Principle Stable 1→1	Principle Loss 1→0	Problem Solving Gain 0→1	Problem Solving Stable 0→0	Problem Solving Stable 1→1	Problem Solving Loss 1→0	Supraordinate-Subordinate Gain 0→1	Supraordinate-Subordinate Stable 0→0	Supraordinate-Subordinate Stable 1→1	Supraordinate-Subordinate Loss 1→0
Block 1 (n = 48)	No.	0	48	0	0	0	48	0	0	3	45	0	0
	Prop.	.00	1.00	.00	.00	.00	1.00	.00	.00	.06	.94	.00	.00
Block 2 (n = 71)	No.	3	68	0	0	12	59	0	0	16	44	5	6
	Prop.	.04	.96	.00	.00	.17	.83	.00	.00	.23	.62	.07	.08
Block 3 (n = 78)	No.	19	50	4	5	23	46	4	5	23	46	5	4
	Prop.	.24	.64	.05	.06	.29	.59	.05	.06	.29	.59	.06	.05
Block 4 (n = 78)	No.	10	19	41	8	24	19	30	5	14	30	20	14
	Prop.	.13	.24	.53	.10	.31	.24	.38	.06	.18	.38	.26	.18
All Grades (N = 275)	No.	.32	185	45	13	59	172	34	10	56	165	30	24
	Prop.	.12	.67	.16	.05	.21	.63	.12	.04	.20	.60	.11	.09

KEY:

Gain: 0→1 = Fail year 1, pass year 2
Stable: 0→0 = Fail year 1, fail year 2
Stable: 1→1 = Pass year 1, pass year 2
Loss: 1→0 = Pass year 1, fail year 2

years. A performance loss occurred if the child mastered the subtest year 1 but failed to do so year 2.

Examination of row one in Table 35 reveals that neither as kindergarteners nor as first graders were any Block 1 children able to master the principles or problem solving subtests in terms of the pass/fail criteria. Three Block 1 children were able to master the supraordinate-subordinate subtest by year 2. Data presented for Block 2 children begin to show some gains in mastery from first to second assessments especially on problem solving and supraordinate-subordinate, although 96 percent of Block 2 children were still unable to master the principles subtest in either 1973 or 1974. As seventh graders, Block 3 children made some notable gains in mastery of all three uses over their performance as sixth graders. The largest percentage of children in Block 3, however, failed each of the concept uses both years. In addition, six percent of these children failed to master principles and problem solving and five percent failed to master supraordinate-subordinate after doing so at the initial assessment. Nevertheless, we observe in Table 35 a small number of Block 3 children who consistently mastered the uses of the equilateral triangle concept in both years of longitudinal assessment. The largest proportion of Block 4 children were either able to master the concept uses at first and second assessments or did so by year 2. In Block 4 only 24 percent of the children failed to master principles both years, 24 percent similarly failed to master problem solving and 38 percent did not meet criterion for mastery of the supraordinate-subordinate subtest either year. In this block we also find that 10 percent of the children mastered principles year 1 but not year 2,

6 percent lost mastery of problem solving and 18 percent, supraordinate-subordinate.

The bottom row of Table 35 presents these data combined across blocks. The percentage of children showing loss of mastery from 1973 to 1974 was quite small for each of the uses. Percentages of all children who were unable to master the uses subtests either year 1 or year 2 were fairly large: 67 percent showed unchanged inability to master principles; 63 percent, problem solving; and 60 percent, supraordinate-subordinate. Children showed greatest mastery gains from 1973 to 1974 on problem solving (21 percent), next on supraordinate-subordinate (20 percent) and least on principles (12 percent). Combining the children who gained in mastery from year 1 to year 2 with the children who fully mastered the uses subtests both years of assessment shows that 34 percent of the longitudinal sample (93 children) mastered problem solving by or before year 2; 31 percent (86 children) mastered supraordinate-subordinate by or before year 2; 28 percent (77 children) mastered the principles subtest in both years or by year 2.

In summary, prediction eight receives support from these descriptive data. Moreover, with increasing grade block increasing numbers of children exhibited either (1) stable mastery of a use from year 1 to year 2 or (2) mastery by the 1974 assessment.

PROGRESS IN MASTERY OF THE LABELS

One of the major propositions of the CLD model is that acquisition of the labels of a concept and its attributes is closely related to concept development and use. It was predicted that as each grade group is followed during longitudinal assessment, percentages of vocabulary items correct will

increase. Table 36 presents mean number of vocabulary items correct for each grade block for each year of assessment. Both within and across grade blocks there was a steady increase in mean number of correct vocabulary items. Close inspection reveals that within blocks the largest spurt in acquisition occurred in Block 1; an average of .40 items was passed in 1973 compared to a mean of 1.88 in 1974. Block 2 children obtained a mean of 2.85 vocabulary items correct at the first assessment and 3.96 at the second. Block 3 children obtained a mean of 4.38 items year 1 and 5.19 year 2. The smallest increment from year 1 to year 2 occurred in Block 4 children; as ninth graders they obtained a mean of 5.94 items and as tenth graders, 6.17 items. Clearly, with each year of longitudinal assessment acquisition of the labels of the concept equilateral triangle, and its attributes, increased and no reversals to the predicted direction were exhibited.

The final prediction to be evaluated in this chapter stated that within each grade block, children gaining in number of vocabulary items passed, compared to the previous year, will also gain in number of uses items passed, compared to the previous year. Of the total number of children in each block gaining in vocabulary items, Table 37 shows the number and proportion gaining, remaining the same or losing combined uses items from year 1 to year 2. For example, of the 34 Block 1 children gaining in vocabulary items, 2 (6 percent) also gained on combined uses items and 32 (94 percent) did not differ in performance on uses items from year 1 to year 2. These data reflect an overall inability of the youngest children to master the uses subtests, as noted earlier. In contrast, of the 45 Block 2 children who gained vocabulary items, 42 percent also gained in combined uses items

TABLE 36

GRADE BLOCK MEANS AND STANDARD DEVIATIONS
FOR CORRECT VOCABULARY ITEMS

		M	S.D.
Block 1	Yr 1	.40	.79
	Yr 2	1.88	1.38
Block 2	Yr 1	2.85	1.58
	Yr 2	3.96	1.71
Block 3	Yr 1	4.38	1.72
	Yr 2	5.19	1.47
Block 4	Yr 1	5.94	1.39
	Yr 2	6.17	1.18

TABLE 37

RELATIONSHIP BETWEEN GAIN IN VOCABULARY ITEMS FROM YEAR 1 TO YEAR 2 AND PERFORMANCE ON COMBINED USES ITEMS: NUMBER AND PROPORTION GAINING, REMAINING STABLE OR LOSING USES ITEMS

	Performance on Combined Uses Items		
	Gain Year 2	Same Year 1 and 2	Loss Year 2
Block 1 (n = 48)			
N Gaining in Vocab. Items = 34			
N	2	32	0
Proportion	.06	.94	.00
Block 2 (n = 71)			
N Gaining in Vocab. Items = 45			
N	19	25	1
Proportion	.42	.56	.02
Block 3 (n = 78)			
N Gaining in Vocab. Items = 49			
N	27	18	4
Proportion	.55	.37	.08
Block 4 (n = 78)			
N Gaining in Vocab. Items = 22			
N	10	10	2
Proportion	.45	.45	.09
All Grades (N = 275)			
N Gaining in Vocab. Items = 150			
N	58	85	7
Proportion	.39	.57	.05

passed. Similarly, 55 percent of the total 49 Block 3 children gaining vocabulary items gained in combined uses items from 1973 to 1974 and 45 percent of the total 22 Block 4 children gaining in vocabulary also gained in combined uses items passed. Across all grade blocks, 150 of the total 275 children gained vocabulary items and of these children, 39 percent also gained in number of items passed on the combined uses subtests. Fifty-seven percent passed the same number of combined uses items year 1 and year 2, although they gained vocabulary items; 5 percent passed fewer combined uses items year 2 than year 1.

Thus, when children who gained in vocabulary items from year 1 to year 2 were examined in terms of their performance on combined uses subtests, more stability than gain was exhibited. This finding generally held both within and across grade blocks and, consequently, has provided no support for the final longitudinal prediction.

V

SUMMARY AND CONCLUSIONS

SUMMARY

The primary objective of the longitudinal research is to chart the conceptual development of children from about age 5 to 18. This goal will be accomplished primarily from analyses of longitudinal data that are collected once each year over a period of four years. The present report, based on the first two years of assessment in the longitudinal research program, has described age changes in children's attainment of the equilateral triangle concept. These descriptive data have been evaluated in terms of ten specific predictions derived from the three major propositions associated with the CLD model.

The predictions are summarized as follows:

1. Children in all grade groups will conform consistently to five acceptable patterns of mastery of the four concept levels during each year of longitudinal assessment.
2. (a) Retesting in the longitudinal assessment will not have a significant influence on the number and proportion of children conforming to predicted patterns.

   (b) Cohort differences will not have a significant influence on number and proportion of children of any specific age conforming to predicted patterns.

3. (a) Retesting in the longitudinal assessment will not have a significant influence on the number and proportion of children attaining each of the four concept levels.

   (b) Cohort differences will not have a significant influence on the number and proportion of children of a specific age who fully attain each of the four concept levels.

4. In accord with the invariant sequence prescribed by the model, a child will master a concept at the same level as the previous year or at higher levels of attainment in the sequence.

5. Children who attain a concept to only concrete and/or identity levels by year 2 will only be able to use that concept in understanding simple perceptual problems.

6. A higher proportion of children who have fully attained the formal level by year 2, in comparison with those whose highest level of attainment by year 2 is classificatory, will also fully master each of the three concept uses. More specifically, a higher proportion of children whose highest level of attainment was at classificatory year 1 and who attain to formal year 2 will master each of the three concept uses when compared to those children whose highest level of attainment was classificatory year 1 and year 2.

7. (a) Retesting in the longitudinal assessment will not have a significant influence on the number and proportion of children who master each of the three concept uses.

   (b) Cohort differences will not have a significant influence on the number and proportion of children of a specific age who master each of the three concept uses.

8. Compared to performance of the previous year, children will either gain or remain stable on mastery of each of the three concept uses.
9. As each grade group is followed during longitudinal assessment, percentage of vocabulary items correct will increase.
10. Children in each grade group gaining in number of vocabulary items passed compared to the previous year, will also gain in number of uses items passed, compared to the previous year.

The preceding predictions were tested using a specially constructed assessment battery for the concept equilateral triangle, the only one of four assessment batteries for which longitudinal data were available at the end of the second year. The equilateral triangle battery consisted of one subtest for each of the four levels of concept attainment and one subtest for each of three concept uses.

The primary target population for longitudinal study was a group of 351 children in Beloit, Wisconsin. In 1973 these children were in kindergarten, third, sixth, and ninth grades; in 1974 the same children were in first, fourth, seventh, and tenth grades. As prescribed by the longitudinal design, two control groups were also used. The control group to assess effects of retesting in the longitudinal study was composed of 160 children (of the same ages and grades as children in the second year of the longitudinal core group). The control group to assess possible cohort differences was composed of 160 children (of the same ages and grades as children in the first year of the longitudinal core group).

Longitudinal data, obtained from a smaller sample of 275 children in Watertown, Wisconsin, were briefly examined to ascertain the extent to which they replicated major findings in Beloit.

On each subtest a child's responses were scored as passing or failing, according to predetermined criteria for each subtest. The data were quantified by computing frequencies and proportions of subjects at each grade who attained each concept level and each uses subtest. Certain post hoc statistical tests were used where appropriate to obtain more specific information about differences in frequencies and proportions. In addition, means and standard deviations of items correct on levels and uses subtests were computed for each grade group during both years of assessment.

CONCLUSIONS

The longitudinal findings will be evaluated in terms of the evidence they provide for each of the predictions. Each prediction is stated, and the evidence is summarized.

1. Children in all grade groups will conform consistently to five acceptable patterns of mastery of the four concept levels during each year of longitudinal assessment. Of the 351 children in the Beloit longitudinal sample, 302 (86 percent) consistently conformed to the predicted invariant sequence. Twenty-nine children, or eight percent, did not conform year 1 but did so by year 2. Only one child failed to follow an acceptable pattern of attainment both years of assessment. Nineteen children, or five percent of the total sample, followed acceptable patterns year 1 but failed to conform year 2. Detailed examination of response protocols for these latter children indicated that most came very close to meeting criterion for subtests that should have been passed according to the CLD model since higher levels were mastered. These instances were attributed to inattentiveness or carelessness during test-taking. Eighty-five percent of the Watertown

longitudinal sample also consistently conformed to the predicted invariant sequence.

It is concluded that both sets of longitudinal data collected over a two year span strongly supported the prediction of conformity to the invariant sequence prescribed by the CLD model.

2. (a) Retesting in the longitudinal assessment will not have a significant influence on the number and proportion of children conforming to predicted patterns.

(b) Cohort differences will not have a significant influence on the number and proportion of children of a specific age conforming to predicted patterns. Statistical tests indicated that neither retesting in the longitudinal program nor cohort differences had a significant influence on the proportion of children conforming to the predicted invarient sequence. The second prediction was clearly upheld.

3. (a) Retesting in the longitudinal assessment will not have a significant influence on the number and proportion of children attaining each of the four concept levels.

(b) Cohort differences will not have a significant influence on the number and proportion of children of a specific age who fully attain each of the four concept levels. Statistical comparisons of core group and control group children attaining each of the concept levels revealed that neither repeated participation in the longitudinal assessment nor being a member of a specific cohort had a systematic biasing influence on attainment of the four concept levels. The third prediction received strong support.

4. In accord with the invariant sequence prescribed by the model, a child will master a concept at the same level as the previous year or at

higher levels of attainment in the sequence. Of the entire Beloit longitudinal sample, 198 children, or 56 percent, attained at the same level as the previous year. This result was largely due to the 109 children who had attained to the highest level of concept mastery both years, reflecting a "ceiling effect" in concept attainment. In addition, 31 percent of the longitudinal sample (110 children) attained a higher concept level the second year of assessment than that attained initially. Thus, 308 children or 88 percent of the longitudinal sample attained at the same level as the previous year or at higher levels. Forty-three children, or 12 percent of the sample, attained at a lower level of mastery year 2 when compared with initial performance. All but 9 of these children attained a single level below their attainment level the preceding year. In most cases, loss of a single item at the higher concept level was responsible for the loss in mastery year 2. Nine children lost two or more concept levels from year 1 to year 2; the most severe losses were incurred by the youngest children in the longitudinal sample and were attributed to carelessness or inattentiveness during the second assessment. Of the 275 children in the Watertown longitudinal sample, 91 percent attained at the same level as the previous year or at higher levels.

These findings are, in general, viewed as strongly supportive of the fourth prediction.

5. Children who attain a concept to only concrete and/or identity levels by year 2 will only be able to use that concept in understanding simple perceptual problems. In the major longitudinal sample in Beloit, no children attained concrete as their highest level year 2 or remained at that level of mastery from year 1 to year 2. Of the four children who gained to identity year 2, none mastered a uses subtest. Of the 14

children at identity both years of assessment, one child mastered the supraordinate-subordinate subtest. In the Watertown longitudinal sample, no children attaining to concrete or identity as their highest level by year 2 mastered any of the uses subtests.

The fifth prediction was clearly borne out by both sets of longitudinal data.

6. A higher proportion of children who have fully attained the formal level by year 2, in comparison with those whose highest level of attainment by year 2 is classificatory, will also fully master each of the three concept uses. More specifically, a higher proportion of children whose highest level of attainment was at classificatory year 1 and who attain to formal year 2 will master each of the three concept uses when compared to those children whose highest level of attainment was classificatory year 1 and year 2. In the Beloit longitudinal sample, as well as in the Watertown sample, statistical tests confirmed significantly superior performance on uses subtests by children attaining at the formal level when compared to those attaining at the classificatory level. In addition, statistical tests confirmed significantly superior performance on the uses subtests by children gaining to formal year 2 from classificatory year 1 in comparison with children remaining at classificatory both years.

It is concluded that both sets of longitudinal data strongly supported the sixth prediction. When compared with attainment at the classificatory level, attainment of a concept at the formal level has a marked facilitative effect on ability to use the concept.

7. (a) Retesting in the longitudinal assessment will not have a significant influence on the number and proportion of children who master each of the three concept uses.

(b) Cohort differences will not have a significant influence on the number and proportion of children of a specific age who master each of the three concept uses. Statistical comparisons between year 2-core group and retest control group children showed that repeated participation in the longitudinal assessment had no marked or systematic biasing effects on performance on uses subtests. Statistical comparisons between children in the core longitudinal sample, year 1, and children in the cohort control group indicated significantly superior mastery of several of the uses subtests by third-, sixth-, and ninth-grade cohort children. Further investigation indicated that superior performance on uses subtests by cohort control group children was not readily explained in terms of differences in intellectual achievements, curriculum changes in the school, or any marked degree of information exchange among students. Superior performance on uses subtests by the cohort children was attributed, speculatively, to situational differences during test-taking (group size and tester differences, or a combination of these two factors).

Therefore, the seventh prediction was supported only insofar as no biasing effects of retesting were found on children's ability to master the uses of equilateral triangle. The continued participation of the cohort control group children in the longitudinal program should aid in elucidating the observed performance differences.

8. Compared to performance of the previous year, children will either gain or remain stable on mastery of each of the three concept uses. Descriptive data from the Beloit longitudinal sample showed that 30 percent of the sample (105 children) mastered problem solving by or before year 2; 21 percent (73 children) mastered principles by or before year 2; and 20

percent (71 children) mastered supraordinate-subordinate in both years or by year 2. At the same time, 75 percent (264 children) did not master the principles subtest in year 1 or year 2; similarly 69 percent (243 children) failed to master problem solving and 76 percent (266 children) failed to master supraordinate-subordinate in either year of longitudinal assessment. These data indicated, in general, that a fairly large proportion of children was unable to master the uses subtests by the second year of the longitudinal program. On the other hand, the number of children who mastered a uses subtest in year 1 but failed to do so year 2 was very small; 4 percent of the longitudinal sample showed loss in mastery of principles, 4 percent showed loss in mastery of supraordinate-subordinate, and only 1 percent showed loss in ability to master the problem solving subtest. Moreover, with increasing grade block increasing numbers of children exhibited either stable mastery of a use from year 1 to year 2 or mastery by the second year of assessment. These general trends and findings were clearly replicated in the Watertown longitudinal data.

It is concluded that prediction eight received support from both sets of descriptive, longitudinal data.

9. As each grade group is followed during longitudinal assessment, percentage of vocabulary items correct will increase. Descriptive data from both the Beloit and Watertown longitudinal samples indicated a marked and steady increase in mean number of vocabulary items answered correctly. No reversals to the predicted progression were observed either within or across grade blocks.

10. Children in each grade group gaining in number of vocabulary items passed compared to the previous year, will also gain in number of uses items passed, compared to the previous year. Statistical tests conducted on the Beloit longitudinal data confirmed that of the children gaining in vocabulary from year 1 to year 2, a significantly greater proportion gained in uses items passed year 2 compared to those passing the same number of uses items or losing uses items from year 1 to year 2. This finding, however, was not replicated in the Watertown data. It is concluded, nevertheless, that the major longitudinal data clearly support the prediction regarding acquisition of the labels of the equilateral triangle concept and its relation to ability to use the concept.

Although both sets of data summarized in the present section were based on a minimum of longitudinal information (two measurements), they clearly support the major longitudinal predictions regarding age changes in children's conceptual development. As assessment in the longitudinal program continues, the data will more accurately describe age changes in the acquisition of the equilateral triangle concept, as well as other concepts.

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APPENDIX A

SUPPLEMENTARY LONGITUDINAL DATA
TABLES FOR BELOIT

TABLE A-1

CONTINGENCY MATRIX SHOWING NUMBER OF CHILDREN FOLLOWING EACH OF THE 16 PATTERNS
YEAR ONE AND YEAR TWO: ALL CHILDREN COMBINED

		Year 2															
Year 1	Pattern	FFFF	PFFF	PPFF	PPPF	PPPP	FFFP	FFPF	FFPP	FPFF	FPFP	FPPF	FPPP	PFFP	PFPF	PFPP	PPFP	Total
	FFFF	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	3
	PFFF	0	0	4	3	0	0	0	0	0	0	0	0	0	0	0	0	7
	PPFF	1	0	14	33	6	0	0	0	0	0	0	0	1	0	0	2	57
	PPPF	3	0	13	64	46	0	0	0	0	0	2	0	0	0	0	5	133
	PPPP	0	0	3	14	95	0	0	0	0	0	0	1	0	0	0	8	121
	FFFP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	FFPF	0	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	4
	FFPP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	FPFF	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	6
	FPFP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	FPPF	0	0	3	2	0	0	0	0	0	0	0	0	0	0	0	1	6
	FPPP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	PFFP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	PFPF	0	0	1	5	0	0	0	0	0	0	0	0	0	0	0	0	6
	PFPP	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
	PPFP	0	0	1	2	4	0	0	0	0	0	0	0	0	0	0	0	7
	Total	4	1	40	133	153	0	0	0	0	0	2	1	1	0	0	16	351

TABLE A-2

PASS/FAIL PATTERNS FOR EACH SUBJECT IN EACH GRADE BLOCK NOT CONFORMING YEAR 2 AND ITEMS CORRECT AT EACH CONCEPT LEVEL NOT ATTAINED

		Pattern Yr. 1	Yr. 2	No. of Items Correct on Subtest Not Attained
Block 1	1	PPFF	PPFP	0 of 3 classif. items year 2; 1 of 3 year 1
	2	PPFF	PPFP	2 of 3 classif. items year 2; 1 of 3 year 1
	3	PPPF	FPPF	5 of 8 concrete items year 2; all year 1
Block 2	1	PPPP	PPFP	2 of 3 classif. items year 2; all year 1
	2	PPPF	PPFP	1 of 3 classif. items year 2; all year 1
	3	PPPP	FPPP	5 of 8 concrete items year 2; all year 1
	4	PPPF	PPFP	1 of 3 classif. items year 2; all year 1
	5	PPFF	PFFP	0 of 3 classif. items year 2; 1 year 1 and 6 of 8 identity items year 2; all year 1
	6	PPPF	FPPF	5 of 8 concrete items year 2; all year 1
	7	FPPF	PPFP	2 of 3 classif. items year 2; all year 1
Block 3	1	PPPF	PPFP	2 of 3 classif. items year 2; all year 1
	2	PPPF	PPFP	2 of 3 classif. items year 2; all year 1
	3	PPPP	PPFP	2 of 3 classif. items year 2; all year 1
	4	PPPP	PPFP	0 of 3 classif. items year 2; all year 1
	5	PPPP	PPFP	2 of 3 classif. items year 2; all year 1
	6	PPPP	PPFP	2 of 3 classif. items year 2; all year 1
	7	PPPF	PPFP	2 of 3 classif. items year 2; all year 1
Block 4	1	PPPP	PPFP	0 of 3 classif. items year 2; all year 1
	2	PPPP	PPFP	0 of 3 classif. items year 2; all year 1
	3	PPPP	PPFP	1 of 3 classif. items year 2; all year 1

TABLE A-3

ITEM PERFORMANCES ON HIGHER LEVELS FOR CHILDREN SHOWING PASS/FAIL STABILITY IN HIGHEST LEVEL OF CONCEPT ATTAINMENT FROM YEAR ONE TO YEAR TWO

Subjects	Pattern Yr. 1	Pattern Yr. 2	Item Performance at Higher Levels
Block 1			
1	PPFF	PPFF	-1 classif; +2 formal (1 vocab, 1 DA)
2	PPPF	PPPF	formal same (same 4 items correct yrs. 1 and 2)
3	PPPF	PPPF	+5 on formal (+3 vocab, +2 DA)
4	PPFF	PPFF	-1 classif; +3 formal (+1 vocab, +2 DA)
5	PPFF	PPFF	classif same (2 items); +4 formal (+3 vocab, +1 DA)
6	PPPF	PPPF	formal same (4 items correct yrs. 1 and 2)
7	PPFF	PPFF	+2 classif; +3 formal (+2 vocab, +1 DA)
8	PFPF	PPPF	+3 formal (+3 vocab, 0 DA)
9	PFPF	PPPF	+1 formal (+1 DA); +4 identity
10	PPPF	PPPF	-2 formal (-1 vocab, -1 DA)
11	PPPF	PPPF	+1 formal (+1 vocab, stable DA)
12	PPFF	PPFF	+1 classif; +4 formal (+3 vocab; +1 DA)
13	PPPF	PPPF	+1 formal (+2 vocab; -1 DA)
14	PPPF	PPPF	+1 formal (-1 vocab; +2 DA)
15	FFPF	PPPF	+5 formal (+2 vocab; +3 DA); +2 concrete; +4 identity
16	PPPF	PPPF	+3 formal (+1 vocab; +2 DA)
17	PPFF	PPFF	same classif (2 items); same formal (3 items)
18	PPPF	PPPF	+1 formal (+3 vocab; -2 DA)
19	PPPF	PPPF	+2 formal (vocab same, 1 item; +2 DA)
20	PFPF	PPPF	-1 formal (+1 vocab; -2 DA); +4 identity
21	FFPF	PPPF	same formal (5); +2 concrete and identity
22	PPFF	PPFF	same classif (2); +4 formal (+1 vocab; +3 DA)
23	PPPF	PPPF	+4 formal (+3 vocab; +1 DA)
24	PPFF	PPFF	same classif (2); +4 formal (+4 vocab, same DA = 2)
25	PPFF	PPFF	-2 classif; +3 formal
26	PPFF	PPFF	same classif (2 items); -2 formal (same vocab; -2 DA)
27	PPPF	FPPF	-1 formal (-1 DA); -3 concrete
Block 2			
1	PPPF	PPPF	+2 formal (+1 vocab; +1 DA)
2	PPPP	FPPP	(loss of 3 items on concrete)
3	PPFF	PPFF	+1 classif; -1 formal (-1 vocab; same on DA)
4	PPPF	PPPF	+1 formal (+2 vocab; -1 DA)
5	PPPP	PPFP	-1 on classif
6	PPPF	PPPF	+4 formal (+2 vocab; +2 DA)
7	PPPF	PPPF	same on formal (7 items)
8	PPFP	PPPP	same on formal (8 items); +1 classif

Continued on next page.

TABLE A-3, continued.

Subjects	Pattern Yr. 1	Pattern Yr. 2	Item Performance at Higher Levels
9	PPPF	PPPF	-2 on formal (-1 vocab; -1 DA)
10	PPPF	PPPF	+1 on formal (+1 DA; same on vocab = 4 items)
11	PPPF	PPPF	+2 on formal (+2 vocab; same on DA = 3 items)
12	PPFF	PPFF	same on classif (0); +2 formal (+2 vocab)
13	FPPF	PPPF	same on formal (6 items)
14	PPPF	PPPF	same on formal (6 items)
15	PPPF	PPPF	+2 on formal (+2 vocab)
16	PPPF	PPPF	-1 on formal (-1 DA)
17	PPPF	PPPF	-1 formal (-1 DA)
18	PPPF	PPPF	+2 on formal (-1 vocab; +3 DA)
19	PPPF	PPPF	+3 on formal (+3 vocab)
20	PPPF	PPPF	same on formal (6 items)
21	PPPF	PPPF	+4 on formal (+2 vocab; +2 DA)
22	PPPF	PPPF	+1 on formal (-2 vocab; +3 DA)
23	PPPF	PPPF	-1 on formal (-1 vocab)
24	PPPP	PPPP	same items passed yrs. 1 and 2
25	PPPF	PPPF	+2 formal (+1 vocab; +1 DA)
26	PFPP	PPPP	same on formal; +2 identity
27	PPPP	PPPP	same performance yrs. 1 and 2
28	PPPF	PPPF	-2 on formal (-1 vocab; -1 DA)
29	PPPF	PPPF	-1 formal (+2 vocab; -3 DA)
30	PFPF	PPPF	+2 formal (-1 vocab; +3 DA)
31	PPPP	PPPP	+2 formal (+1 vocab; +1 DA)
32	PPPF	PPPF	+1 formal (-1 vocab; +2 DA)
33	PFPF	PPPF	-2 formal (-1 vocab; -1 DA); +2 identity
34	FPPF	PPPF	same on formal (6 items); +2 concrete
35	PPPF	PPPF	+2 formal (+2 vocab)
36	PPPF	PPPF	+1 formal (+1 DA)
37	PPPF	PPPF	-3 formal (-4 vocab; +1 DA)
38	PPPF	PPPF	same on formal (6 items)
39	PPPP	PPPP	same performance yrs. 1 and 2
40	PPFF	PPFF	+1 classif; +7 formal (+4 vocab; +3 DA)
41	PPPF	PPPF	+3 formal (+2 vocab; +1 DA)
42	PPPF	PPPF	same on formal (7 items)
43	PPPP	PPPP	same performance yrs. 1 and 2
44	PPPF	PPPF	-4 formal (-4 vocab; same DA = 0)
45	PPPF	PPPF	+2 formal (+2 vocab; same DA = 3)
46	PPPF	PPPF	+3 formal (+2 vocab; +1 DA)
47	PPPF	FPPF	+1 formal (+1 vocab; same DA = 3); -3 concrete
48	PPPP	PPPP	+1 formal (+1 vocab)
Block 3			
1	PPPF	PPPF	same performance on formal (7 items; 4 vocab, 3 DA)
2	PPPF	PPPF	+1 formal (+1 vocab; same on DA = 3 items)

Continued on next page.

TABLE A-3, continued.

Subjects	Pattern Yr. 1	Pattern Yr. 2	Item Performance at Higher Levels
3	PPPF	PPPF	-1 formal (-1 vocab; stable on DA = 3 items)
4	PPPF	PPPF	+4 formal (+1 vocab; +3 DA)
5	PPPF	PPPF	+1 formal (+1 vocab; stable on DA = 3 items)
6	PPPF	PPPF	same on formal (5 items)
7	PPPF	PPPF	+3 formal (+1 vocab; +2 DA)
8	PPPF	PPPF	+1 formal (+1 vocab; stable on DA = 3 items)
9	PPPF	PPPF	+3 formal (+1 vocab; +2 DA)
10	PPPF	PPPF	same performance on formal (7 items)
11	PPPF	PPPF	+1 on formal (+1 vocab)
12	PPPF	PPPF	-3 formal (-3 vocab)
13	PPPF	PPPF	+1 formal (+1 vocab, stable on DA = 3)
14	PPPF	PPPF	-2 vocab; +3 DA
15	PPPF	PPPF	-1 formal (-1 vocab; stable on DA = 3)
16	PPPF	PPPF	same performance on formal
17	PPPF	PPPF	+1 formal (+2 vocab; -1 on DA)
18	PPPF	PPPF	+2 formal (+2 vocab; stable on DA = 1)
19	PPFF	PPFF	classif same (0); +1 vocab; +1 DA)
20	PPPF	PPPF	-1 formal (+2 vocab; -3 DA)

(Remaining Block 3 subjects showing highest level of attainment unchanged from year 1 to year 2 were at formal both years of longitudinal assessment, N = 36)

Block 4

1	PPPF	PPPF	stable on formal (3 vocab and 3 DA)
2	PPPF	PPPF	-4 formal (-6 vocab; +2 DA)
3	PPPF	PPPF	+1 formal (+1 vocab; stable on DA = 2 items)
4	PPPF	PPPF	+1 formal (+1 vocab; stable on DA = 0 items)

(Remaining Block 4 subjects showing highest level of attainment unchanged from year 1 to year 2 were at formal both years of longitudinal assessment, N = 63)

Key:

classif = classificatory
vocab = vocabulary
DA = discriminating attributes

TABLE A-4

ITEM PERFORMANCES OF CHILDREN SHOWING PASS/FAIL LOSS IN HIGHEST LEVEL OF MASTERY FROM YEAR ONE TO YEAR TWO

Subjects	Pass/Fail Pattern Yr. 1	Yr. 2	Item Performance
Block 1			
1	PPPF	PPFF	-1 classif; +3 vocab; +1 DA
2	PFPF	PPFF	+2 identity; -1 classif, +3 vocab; +2 DA
3	FFPF	PFFF	+2 concrete; +1 identity; -1 classif; -1 DA
4	FPPF	PPFF	+3 concrete; +1 identity; -1 classif; -1 vocab; +3 DA
5	PPPF	PPFF	-1 classif; stable on formal (3 vocab; 0 DA)
6	FPPF	PPFF	+1 concrete; -2 classif; +1 vocab
7	PPPF	PPFF	-1 classif; -1 vocab
8	PPFF	FFFF	-2 concrete; -2 identity; -2 classif; -1 DA
9	PPPF	FFFF	-2 concrete; -2 identity; -3 classif; +3 vocab; +2 DA
10	PPPF	FFFF	-2 concrete; -1 identity; -2 classif; +1 DA
11	FFPF	PPFF	+8 concrete; +8 identity; -1 classif; +1 vocab; +1 DA
12	PPPF	FFFF	-1 concrete; -1 identity; -3 classif; stable on formal (4 vocab; 4 DA)
Block 2			
1	PPPP	PPPF	-1 vocab; stable DA = 3
2	PPPF	PPFF	-2 classif; -1 vocab; -1 DA
3	PPPP	PPPF	-1 vocab item
4	PPPF	PPFF	-1 classif; +2 vocab; stable DA = 3
5	PPPP	PPPF	-1 vocab; +1 DA
6	PPPF	PPFF	-1 classif;stable formal (1 vocab; 2 DA)
7	PPPF	PPFF	-1 classif; stable formal (4 vocab; 3 DA)
8	FPPF	PPFF	+2 concrete; -1 classif; stable formal (3 vocab; 3 DA)
9	PPPF	PPFF	-1 classif; +2 vocab; -1 DA
10	PPPF	PPFF	-3 classif; -1 vocab; stable DA = 3
11	PPPP	PPPF	-3 vocab; stable DA = 2
12	PPFP	PPPF	+3 classif; -2 vocab; stable DA = 2
Block 3			
1	PPPF	PPFF	-1 classif; -1 vocab; stable DA = 0
2	PPPP	PPPF	-2 vocab; stable DA = 3
3	PPPP	PPPF	-2 vocab; stable DA = 3
4	PPPF	PPFF	-1 classif; stable formal (6 items)
5	PPPP	PPPF	-2 vocab; stable DA = 3
6	PPPP	PPFF	-1 classif; -4 vocab; stable DA = 3
7	PPPP	PPPF	-3 vocab; stable DA = 3

Continued on next page.

TABLE A-4, continued.

Subjects	Pass/Fail Pattern Yr. 1	Yr. 2	Item Performance
8	PPPP	PPPF	-2 vocab; stable DA = 3
9	PPPP	PPPF	-1 vocab; +1 DA
10	PPFP	PPFF	-4 vocab; stable DA = 3
Block 4			
1	PPPF	PPFF	-1 classif; +2 vocab; -2 DA
2	PPPP	PPPF	-1 vocab; stable DA = 3
3	PPPP	PPFF	-1 classif; -1 vocab; stable DA = 3
4	PPFP	PPPF	+1 classif; -5 vocab; -3 DA
5	PPPP	PPPF	-2 vocab; stable DA = 3
6	PPPP	PPPF	-2 vocab; -2 DA
7	PPPP	PPPF	-3 vocab; +1 DA
8	PPPF	PPFF	-2 classif; +1 DA; vocab stable = 3
9	PPPP	PPFF	-2 classif; -3 vocab; -1 DA

Key:

classif = classificatory
vocab = vocabulary
DA = discriminating attributes

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